January 1981
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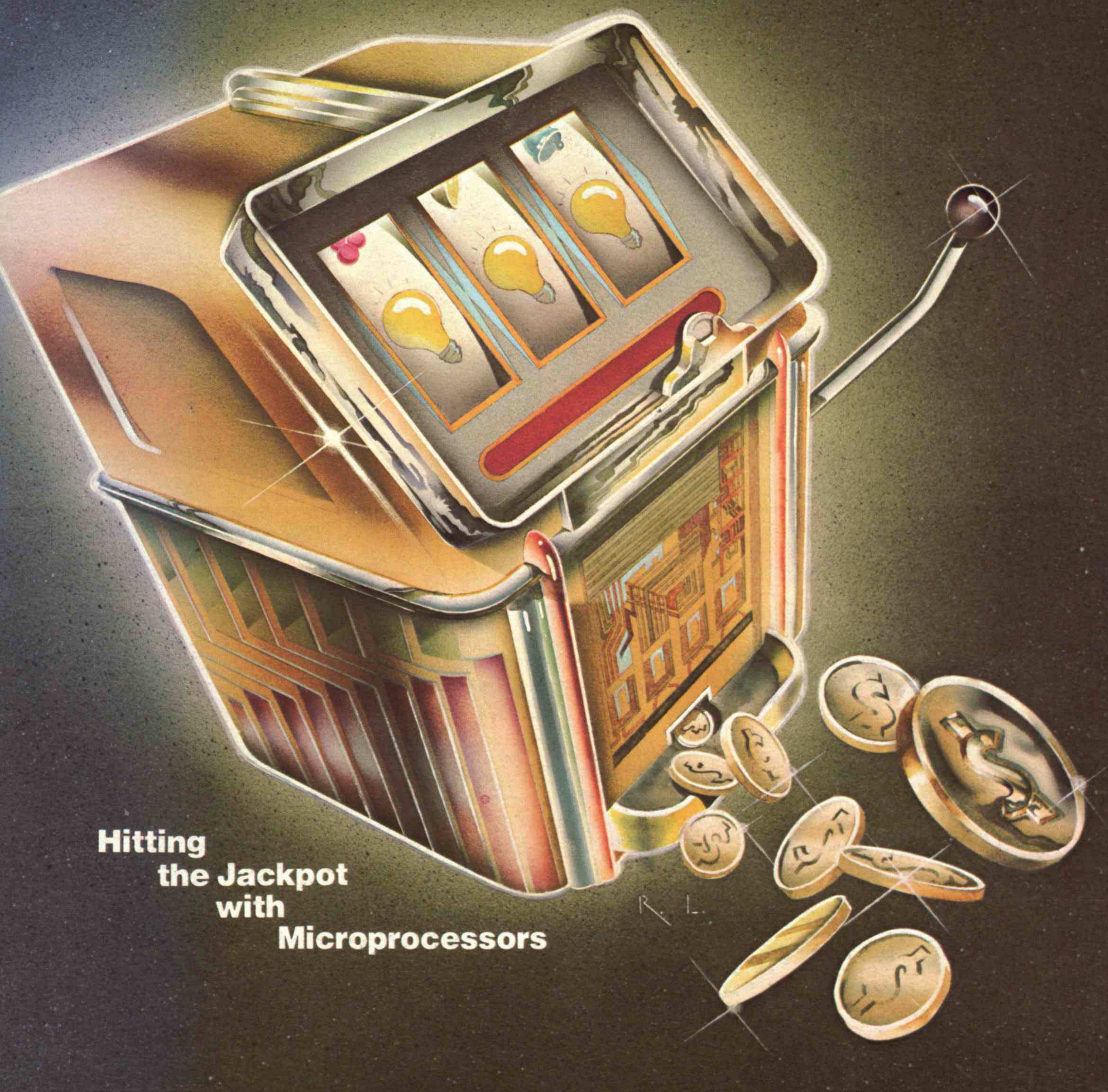
Technology Review

Edited at the Massachusetts Institute of Technology



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Edited at the Massachusetts Institute of Technology
Volume 83, Number 3
January 1981

Technology Review

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Letters

Cooling Off the Nuclear Debate . . .

Professor Michael Golay (*"How Prometheus Came to Be Bound," June/July, p. 28*) characterizes as extreme the view that nuclear power is essential to the nation in its appropriate role — a share of base-load capacity. That position is by no means extreme; this temperate goal has been made to seem extreme by the tactics of its adversaries.
A. David Rossin
Chicago, Ill.

Dr. Rossin is systems nuclear research engineer at Commonwealth Edison. Professor Golay responds:
There is a large difference between saying that nuclear power is essential to the nation's economy and saying (as I believe is true) that it is very beneficial but not essential. The hyperbole that David Rossin objects to my calling extreme is exactly the sort of myth regarding nuclear power that the American utility industry has endorsed repeatedly, to the deception of itself as well as the public. An additional example of such a myth is the assertion of the urgent need for development of a commercial breeder reactor — a development that I think would be a clear social benefit but upon which national economic health is unlikely to depend strongly during my lifetime.

It is difficult when hard pressed by adversaries to avoid taking extreme positions, but by their gratuitous defense of dubious extreme positions, American utilities have made their socially valuable work needlessly difficult. It would be good for everyone if our public debates could be characterized more by candor and self-doubt regarding sacred dogma.

. . . and Heating It Up Again

In response to Professor Golay's views on nuclear licensing, I have some advice: if your nuclear project encounters regulatory obstacles, especially environmental ones, never publicly criticize the specific regulations to which you object. Rather, speak in sweeping, general terms about how environmental laws should be more "reasonable," "objective," "responsible," or "balanced." Just say that environmental requirements are too "legalistic" and "burdensome," that they need to be "finely tuned" for a more "rational" implementation. After all, who can argue with someone who advocates "rationality"? If these sweeping generalities don't work, you can claim that without nuclear power there will certainly be blackouts and "economic pain." And if this is disputed, you'll have to fall back on the argument that nuclear power is best for utility companies and their investors (in contrast to consumers), and that what's best for investors is best for America. This advice is obviously inapplicable to irrational, unreasonable, no-growth utopian socialist ecofreaks.
Michael Philips
Washington, D.C.

Professor Golay responds:
Too much of the national discussion of nuclear power (and many other issues as well) has been characterized by straw-man arguments, insinuations of sinister intent, and general meanness of spirit. Until this climate changes, the quality of our public life will remain degraded and the policies it produces will continue to fail to serve the common good.

Advertising out of Context

Dow Chemical Co.'s messages that "without chemicals, life itself would be impossible" are obviously not addressed to your writers (*"On the Semantic Dissolution of Risk" in Trend of Affairs, June/July, p. 85*); they are addressed to those of the general public whose thinking already involves a "breathtaking leap of illogic" leading to "a simplistic, general condemnation of 'chemicals.'" Advertising campaigns cannot be judged without considering who they are addressed to and what they are trying to accomplish.
George Elwers
Naugatuck, Conn.

Avoiding the Search for Truth?

In contrast to the views in "Inedible Fruits of Military Spending" and "Military Spending: The Right Solution at the Wrong Time" (*Trend of Affairs, June/July, pp. 78-79*), the inflation from which we are suffering has been caused mainly by the government ballooning the money supply to pay for the unfunded huge increases in "transfer" payments, by massive unnecessary government regulation that has reduced productivity, and tax policies that have discouraged saving and investment in more efficient means of production.

The majority of American voters share

Our earnings are the fuel for finding new American energy.

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At Amoco we are convinced that the best way to spend our money is to find the energy that will make America less dependent on foreign oil. Last year that commitment added up to $1.5 billion spent here in the U.S. and that made us the industry drilling leader. This year we'll spend even more... close to $2 billion.

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the concern that inadequate defense spending has allowed the Soviets' military capability to gain on that of the free world, to the point that the Soviets are able to expand with impunity by the use of naked military force. Of course, there are many pacifists and liberals among your readers, but there are also those who love freedom and worry about our Russian opponents and our "Big Brother" government. Where are the articles and arguments for the latter in your magazine? Or are you in fact avoiding a genuine search for truth?
H. Richard Johnson
Palo Alto, Calif.

A Benevolent Godfather or People Governing People?

"Saving American Democracy" won't be possible if relevant facts are ignored or suppressed. John Kemeny (*"The Lessons of Three Mile Island," June/July, p. 64*) has repeated the assertion of the President's Commission by stating that there will be no — or practically no — health effects from this accident. But Dr. Kemeny should spend a bit more time reviewing the literature on the effects of low-level radiation to prepare to deny the now-omnipotent utility hype that "no one died at Three Mile Island."
Geoffrey A. Dean
Surrey, B.C., Canada

Dr. Kemeny failed to learn from his experience with the Three Mile Island accident; he ends up proposing a new American democracy — a centrally planned socialist system where "someone" decides what is best for us all.

I propose a viable, efficient, effective, and inexpensive alternative — a return to the free market where political power is banned. Without government involvement, we would either have no nuclear power because of the high cost of producing it safely and insuring its producers; or safe nuclear power, because if it can be produced safely, utilities and insurers alike would profit. We would not have a potentially dangerous industry propped up by a government with a vested interest in preserving it, safety or no.
Gary Siebert
Nashua, N.H.

As an engineer, my advice is: give us a chance. To ask a mathematician like John Kemeny to put together a program for avoiding another fiasco like Three Mile Island was a mistake. I distrust scientists because they are elitists without much knowledge of basic economics and are influenced by personal jealousies and political (social) conditions. I have succeeded as an engineer because to the scientists, research metallurgists, and computer experts I have said, "So far and no further."
Norman Weiss
Tucson, Ariz.

The article by John G. Kemeny is . . . the most profound printed in any magazine that I have ever read.
Joseph S. Finger
Houston, Tex.

Input versus Output

J. Scott Armstrong (*"The Seer-Sucker Theory: The Value of Experts in Forecasting," June/July, p. 18*) notes that experts may be engaged because ". . . the client is not interested in accuracy but only in avoiding responsibility. A client who calls in the best wizard available avoids blame if the forecasts are inaccurate." He then goes on to recommend that we ". . . hire inexpensive experts."

Unfortunately, since only expensive experts are perceived as "the best wizards," one must spend freely to avoid blame. Otherwise one is vulnerable to the criticism that "the lawsuit would have been won, or grandma's operation would have been successful, or a favorable administrative ruling would have been obtained if only we had engaged a first-rate lawyer/surgeon/expert *instead* of the mediocrity we got to save money."

As with many other fields of endeavor, when measures of output (here, of competence) are not available, measures of input (here, of costliness) take their place.
Edwin Cohen
Binghamton, N.Y.

The writer is staff scientist at the Link Division of the Singer Co.

Interconnectedness and Universality

I was dismayed by Professor Daniel Kleitman's review of *Gödel, Escher, Bach: An Eternal Golden Braid* by Douglas R. Hofstadter (*"An Enthusiasm Marathon," May, p. 17*). Thank goodness I read the book before seeing the review, for I did not find it patronizing, as Professor Kleitman suggests, unlike his review. Professor Kleitman seems to have mistaken it for a book primarily about mathematics, while I found it to be a truly remarkable experience on the interconnectedness of things and the universality of human ideas.
Thomas C. Horth
Burlington, Mass.

Professor Kleitman responds:
I admire Mr. Hofstadter's style, but, as Mr. Horth deduced, emphasis on "the interconnectedness of things and the universality of human ideas" leaves me cold. However, to each his or her own. I would really like to be proven wrong in my contention that few will finish the book.

Gremlins and Our Art

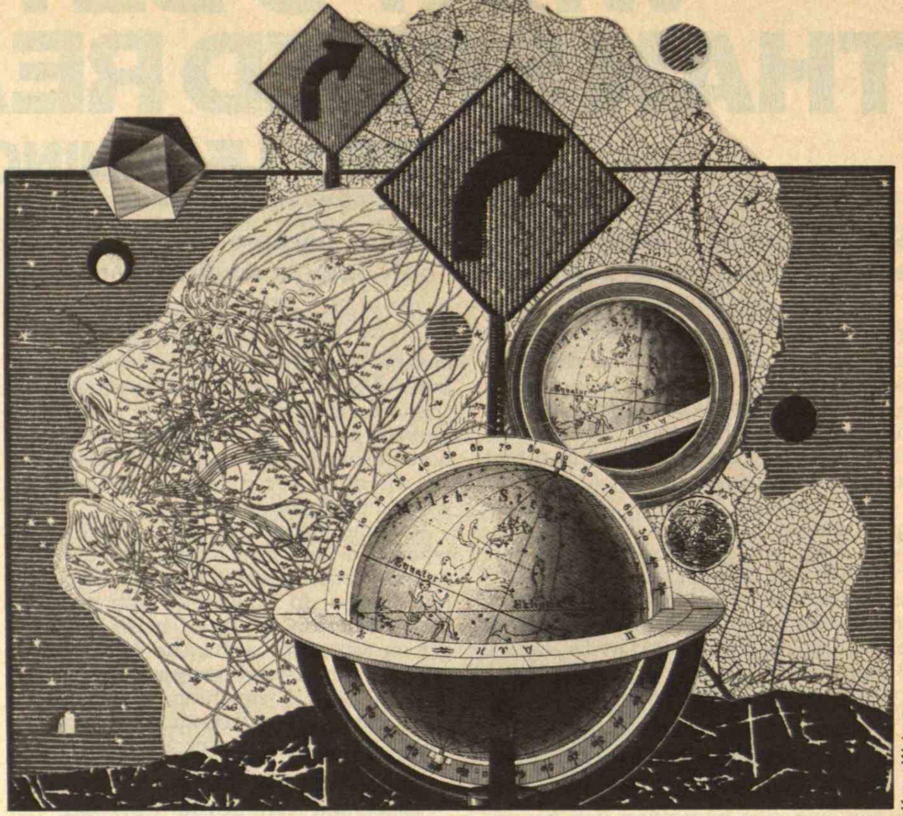
The last two months have been, as the production manager says, "bad ones for credits." The editors hereby acknowledge the contributions of three Boston-area artists to the October and November/December issues:

☐ Colleen, for the calligraphy (*above*) that added so much to "Avoiding Nuclear Holocaust" by Victor A. Weisskopf (*Oct. pp. 28-29, 30, 33, and 34*).
☐ Bruno Joachim, for the photograph of the engineless automobile introducing "Is There a Better Automobile Engine?" (*Nov./Dec., p. 18*).
☐ Renee Klein, for the drawing of the televised breakfast newspaper in "Newspapers versus Computers" (*Nov./Dec., pp. 72-73*).

As these and other illustrators whose work appears in this magazine will readily concede, we are at best miserly in our compensation for the hours they devote to our cause. So we're especially chagrined by these gremlins, and we apologize. — *Ed.*

The Meaning of Development

Kenneth E. Boulding is a program director at the Institute of Behavioral Science and distinguished professor emeritus of economics at the University of Colorado at Boulder.



Karen Watson

THE word *development*, like the word *appropriate*, has the delightful property that nobody can come out against it. The reason may be that nobody really knows what it means, or that to everybody it means different things. To define it may therefore be rather dangerous, but the answer might make a certain amount of sense. What inspires these reflections is the global seminar on the role of professional and scientific societies in development, sponsored by the American Association for the Advancement of Science, the Indian National Science Academy, and the Indian Science Congress Association, held in New Delhi from December 1 to 5.

Like that similar word *evolution*, development means an unfolding, a realization of potential. We see this in the development of a person or, for that matter, a chicken from a fertilized egg. In its genetic information, every fertilized egg contains the potential for an organism. There is never any guarantee, of course, that this potential will be realized, for death can arrest the development process at any time. We have some idea how the information is coded in the DNA molecule, but we do not really know how it organizes the development process, one of the great mysteries of the universe.

In its larger sense, development refers to the whole evolutionary process, the realization of the potential inherent in the Big Bang or whatever started the universe. In the intermediate sense of the New Delhi conference, it is the realization of the potential of the human race, particularly for knowledge, social organization, behavior, production, and destruction.

The potential of the human organism is so enormous that it takes many modes. The mode used most often is that of economic development, which means, crudely, getting richer. In many cases, this potential is not realized: both individuals and societies can stay poor or become poorer. Getting rich means, in the first place, increasing the total per capita stock of valued human artifacts — houses, furniture, clothing, and automobiles. It therefore depends on the potential for production, which in turn depends on knowledge, the one positive factor of production. Energy, materials, space, and time are limiting factors. Even an isolated individual has the potential for getting richer, but the only way everybody can get rich is by realizing the human potential for increased knowledge and productive skill. We can question whether the failure to get richer can be cured by increasing the potential or by diminishing the organizational and cultural structures that frustrate the almost ineradicable potential.

Seeking the Good Life

Riches, however, are potential only for the development of what might be called the "good life." If riches are used unwisely, as they often are, for vulgar display, the satisfaction of corrupt and addictive desires, or the expression of greed or malevolence, the potential for the good life is frustrated.

Another important aspect of development is the realization of the potential for peace. There is also a potential for war. However, war tends to be a negative-sum game that diminishes total human welfare; even victory is often an extremely bitter fruit that contains the seeds of later defeat. Therefore, realization of the potential for peace is a long, slow process. We see progress in the expansion of areas of internal peace within nations and the development of areas of stable peace among nations such as in North America and Scandinavia. How to accelerate this process is a critical question, perhaps for the very survival of the human race.

Closely related is political development, which might be defined as the development of organizational skill and the exercise of legitimate threat systems. It is clear that economic development is not closely related to political ideology, or even to formal political institutions. Some socialist countries get poorer, such as Cambodia today, the First Collectivization of the Soviet Union, and the Great Leap Forward and the Cultural Revolution in China. Some capitalist countries have gotten poorer — the United States in the Great Depression, and Argentina, Uruguay, and Chile in the past generation. Political skill, only loosely related to ideology or forms of government, may well be random; that is, getting skilled people into position of power involves a certain amount of luck. Various ideologies and forms of government may make good political luck more or less probable, but they cannot wholly eliminate this factor. Making political skill more probable is a very important subject for research.

Finally, what do we mean by the de-

velopment of knowledge and skill crucial to the human development process? Indeed, the whole evolution of the universe involves the realization of the potential of genetic structures, the know-how in the fertilized egg or even the carbon atom. With the human race, this expands into "know-what," structures inside the human nervous system that map the patterns of the whole universe through space and time. Economic development, largely the development of human artifacts, is intimately related to human knowledge. There were no hybrid corn plants or automobiles or space probes 50,000 years ago, though there were human beings who had the potential for these things.

Justifying the Means to the End

There are three lines of development, the first of which might be called "folk knowledge," which humans acquire in ordinary daily life. The knowledge and skill to drive a car is folk knowledge, now widely spread in the rich countries, that did not exist 100 years ago. Folk knowledge develops folk technology, such as early agriculture, domestication of livestock, wheeled vehicles, pottery, weaving, and metallurgy. Child rearing, cooking, and the skills of family and community life are also part of this development.

The second line of development goes beyond folk knowledge and technology to specialized arts, literature, religion, money, and symbolism. These evolutionary processes have taught variety, richness, and complexity. The potential of the human race for drama and theatre was not exhausted with Sophocles or even with Shakespeare; devotional experience was never exhausted by the existing forms of religion, as the rise of new varieties continually testifies. What we mean by development in these areas is a difficult and perhaps even dangerous question, but we should not refuse to ask it.

The third field of development is, of course, science and technology, largely a product of the last 500 years, though there were many precursors in India, Babylon, Greece, and China. That science has influenced the direction of human knowledge can hardly be denied; without this subculture, we would not have the chemical or the electrical industry, and neither would we have nuclear weapons.

Development concepts always involve evaluation; there is no way of avoiding normative judgments. Development is a movement from bad to better, rather than bad to worse, but all change is not for the better. Negative potential is realized in increasing poverty, political incompetence, arms races and wars, cultural and religious decay, and even scientific blind alleys. The development of human valuations is therefore a critical part of the total picture. All intermediate goods — that is, things good for something else — have to be justified. This is difficult to evaluate, but substitute measures and the elevation of intermediate goods into things that are good in themselves is one of the great sources of negative development.

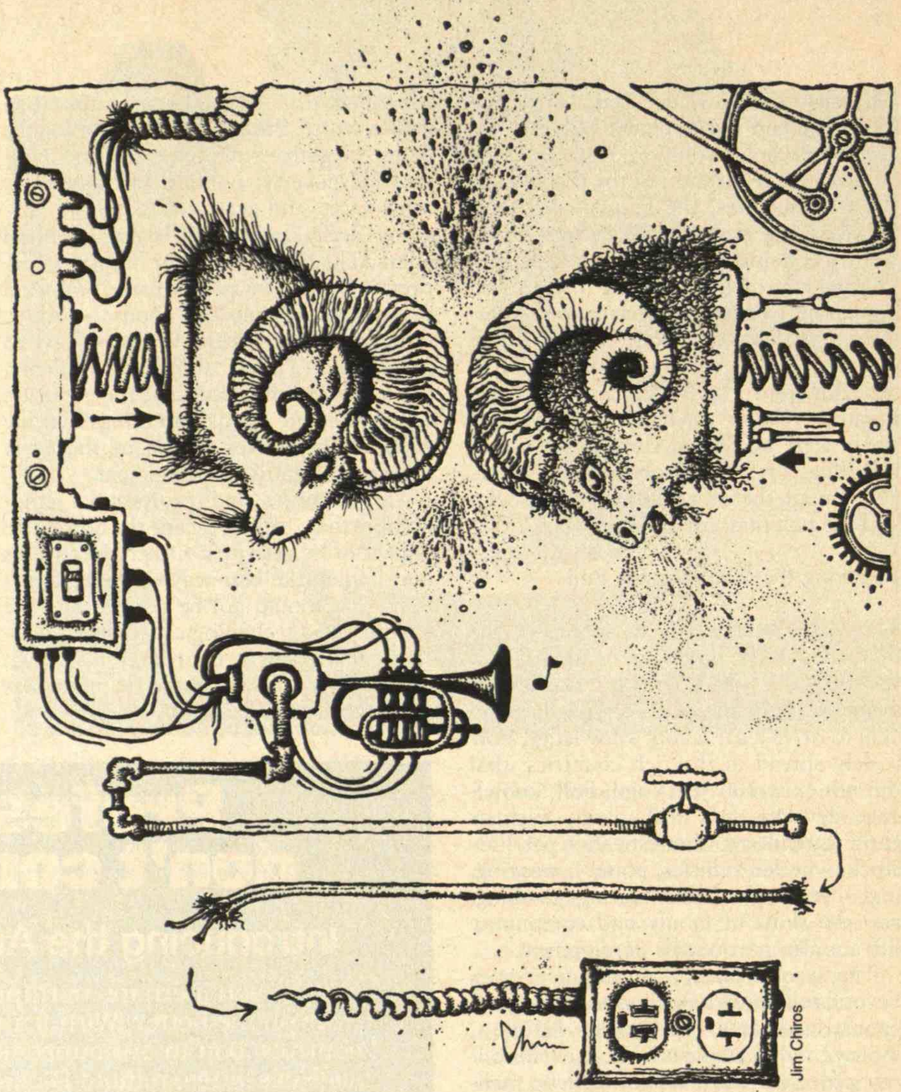
The scientific and professional community, then, cannot escape the normative impact of its activities. Otherwise, it falls into finding the best way of doing something that should not be done at all. The scientific and technological community itself, particularly as expressed in its own organizations, must guard its members against this fallacy. ☐

Forging Ahead with Fusion

Robert C. Cowen, science editor of the Christian Science Monitor, *is former president of the National Association of Science Writers and a regular contributor to the* Review. *He holds S.B. and S.M. degrees in meteorology from M.I.T.*

AFTER a quarter-century of dashed hopes and erratic public support, physicists engaged in the toughest applied-science program ever undertaken — the development of hydrogen fusion power — are at last in sight of their first major goal. By mid-decade, they should have a self-sustaining fusion reaction under control in the laboratory. More important, by 1990 they expect to have learned enough about the engineering of fusion power plants to decide whether a prototype power station is feasible by 2000 and what its design should be.

That may not seem like a big deal in a field where the payoff of practical power generation always seems to be 20 years away. However, it is the first achievement with a definite timetable to which fusion scientists have felt they could commit themselves.



Jim Chiros

Keeping the Faith

There have been other occasions for general optimism. These began, symbolically at least, in 1955, when the late Homi Bhabha of India remarked in opening the first Atoms for Peace conference: "There is no basic scientific knowledge in our possession to show that it is impossible for us to obtain . . . energy from the fusion process . . . I predict that a method will be found for liberating fusion energy in a controlled manner within the next two decades." Impossible, no, but the lack of basic knowledge hid the magnitude of the challenge. Such optimism soon dissipated as the hot gaseous hydrogen fuel, or plasma, revealed yet another trick in avoiding meaningful control. This time one senses things will be different.

The 1970s saw substantial progress. Only two or three years ago, it was considered prudent to plan fusion development on a cautious step-by-step timetable. Some kind of fusion-engineering device (FED) to explore power-reactor engineering had to wait for the ignition of self-sustaining fusion in the laboratory, putting any hope of demonstrating fusion power well into the next century. Now fusion experts feel comfortable in going ahead with an FED right away.

Key experiments at the Princeton Plasma Physics Laboratory and the Massachusetts Institute of Technology support this confidence. Physicists are in sight of the 100-million-degree temperatures needed for ignition, and predictions of plasma conditions as experimental reactors are scaled up in size, plasma density, and temperature are well established.

This progress was recognized a year ago in an International Atomic Energy Agency study, when 400 fusion experts from Europe, Japan, the Soviet Union, and the United States concluded that "it is scientifically and technologically feasible" to have INTOR, an international FED, running by the early 1990s. A Department of Energy (DOE) advisory panel, in a report approved last August, also found that "this next step [an FED] in the fusion program is both sound and timely." The panel urged doubling the U.S. budget for magnetic fusion — fusion with the plasma confined by magnetic force — over the next five to seven years.

Restricted funding has sometimes seemed as discouraging to fusion workers as the ennui of plasmas. When the going got tough, funding in Western countries tended to shrink. Not much more than a decade ago, the late Soviet fusion researcher, Lev Artsimovich, was urging Britain and the United States not to lose faith. The fusion outlook appeared bleak, and both countries had put research on the back burner. Artsimovich insisted that

he could see a brighter future. His vision was partly inspired by the maturing of a Russian concept in magnetic "bottles" called *tokamak*, from the Russian words meaning "torus carrying an electric current." Tokamaks soon became the centerpiece of fusion research around the world: they provided much of the encouraging technical progress of the past decade. Today, they are the most advanced version of magnetic fusion, itself the leading approach to controlling the celestial fire.

Artsimovich turned out to be right, and the Magnetic Fusion Engineering Act of 1980, signed by President Carter on October 7, recognizes the progress. Over the next five years, the general fusion budget, which ran to $355 million in fiscal 1980, will double. Specifically, the act will boost the magnetic fusion budget 50 percent in each of the next two years. It authorizes — indeed mandates — construction of an FED at a new fusion-engineering test center, and it anticipates the building of a demonstration power plant by the century's end. This is the strongest commitment to meaningful long-term support ever given to the American controlled-fusion effort. It does indeed look as though fusion research has turned a significant corner.

A Light at the End of the Tunnel

"At last, we are confident we will have a package we can deliver in 10 years. I'm really excited about it," says John F. Clarke, DOE's deputy associate director for fusion. He explains that it will take about 10 years to establish the engineering test center and build the FED. Thus, the "package" Dr. Clarke expects to deliver in 1990 will include the sound and detailed engineering knowledge needed to specify the design and cost of a prototype power plant.

This knowledge, rather than the FED hardware, is the real prize that fusion experts such as Dr. Clarke are now seeking. For them, a solid concept of a fusion reactor will be as welcome as landfall for Pilgrims arriving in the New World. Although much hard development work will lie ahead, fusion specialists will at last have firm ground under their feet. They will know what needs to be done and whether it is economically as well as technologically feasible.

In spite of the encouraging progress and welcome increase in funding, there has been concern in the fusion community about moving too quickly. Congress, with one eye on the energy supply, has been impatient with the old timetable. Sponsors of the new fusion law have talked glibly of going with the tokamak in an *Apollo* (moon landing) -type crash program. But tokamaks are not the only way of doing this. Mirror machines, in which plasma is confined in a cylinder by electric and magnetic fields that reflect escaping particles back into the "bottle," also show considerable promise. So does the radically different approach of inertial fusion, in which pellets of hydrogen fuel, compressed by laser or particle beams, explode like tiny bombs.

Will Fusion Remain Fashionable?

These and other concepts, to say nothing of the continued development of a wide knowledge base, could be sidetracked by a single-minded drive to bring a tokamak power reactor to maturity. Professor John M. Deutch, former DOE undersecretary, warned during the inaugural symposium for M.I.T. President Paul Gray that "it is quite possible that overly enthusiastic proponents will adversely affect the technology. It is being pushed too fast." This is why DOE planners are emphasizing knowledge, not hardware. Neither the tokamak nor the current mirror concept may be best for a reactor, explains Dr. Clarke. So present planning includes a broad engineering program, of which the fusion-engineering device will be the biggest, but not the only, component.

"A tremendous development of ideas is underway," says Dr. Clarke. "I think what we will have in 1990 is a toroidal device that will incorporate features of several concepts. There will be an advanced mirror, too. For magnetic fusion, we should have a very complete physics and engineering base." The inertial fusion program is also expected to be in an advanced stage.

Thus, a quarter-century after Bhabha made his dramatic — and, as it turned out, naive — prediction, a prototype fusion power plant is still 20 years away. But this time the vision does seem attainable. In fact, the biggest uncertainty isn't even technical. Rather, will the government really follow through on the 20-year commitment implied by the new law, regardless of changes in administration, the makeup of Congress, and the fashions of fusion concepts? ☐

Fear of Lying: Polygraphs in Employment

by Eric P. Matusewitch

Polygraph them all . . . I don't know anything about polygraphs and I don't know how accurate they are, but I know they'll scare the hell out of people."
—Richard M. Nixon, July 24, 1971.

In recent years, the American public has expressed growing concern over the use of the polygraph, or "lie detector," for the selection and management of workers in industry and government. This application of the polygraph, reputed to be commonplace, raises serious questions regarding individual privacy and civil liberties.

All attempts at lie detection from ancient times to the present rely upon the same basic principle — the measurement of certain physiological changes presumed to accompany the psychological stress of telling a lie. For instance, the ancient Chinese believed that the stress of lying inhibits the flow of saliva, making it difficult to chew or swallow dried matter. Hence, suspected liars' veracity was tested by making them chew rice powder and then spit it out. If the powder remained dry — presumably because the stress of being untruthful had inhibited the flow of saliva — the suspect was deemed guilty.

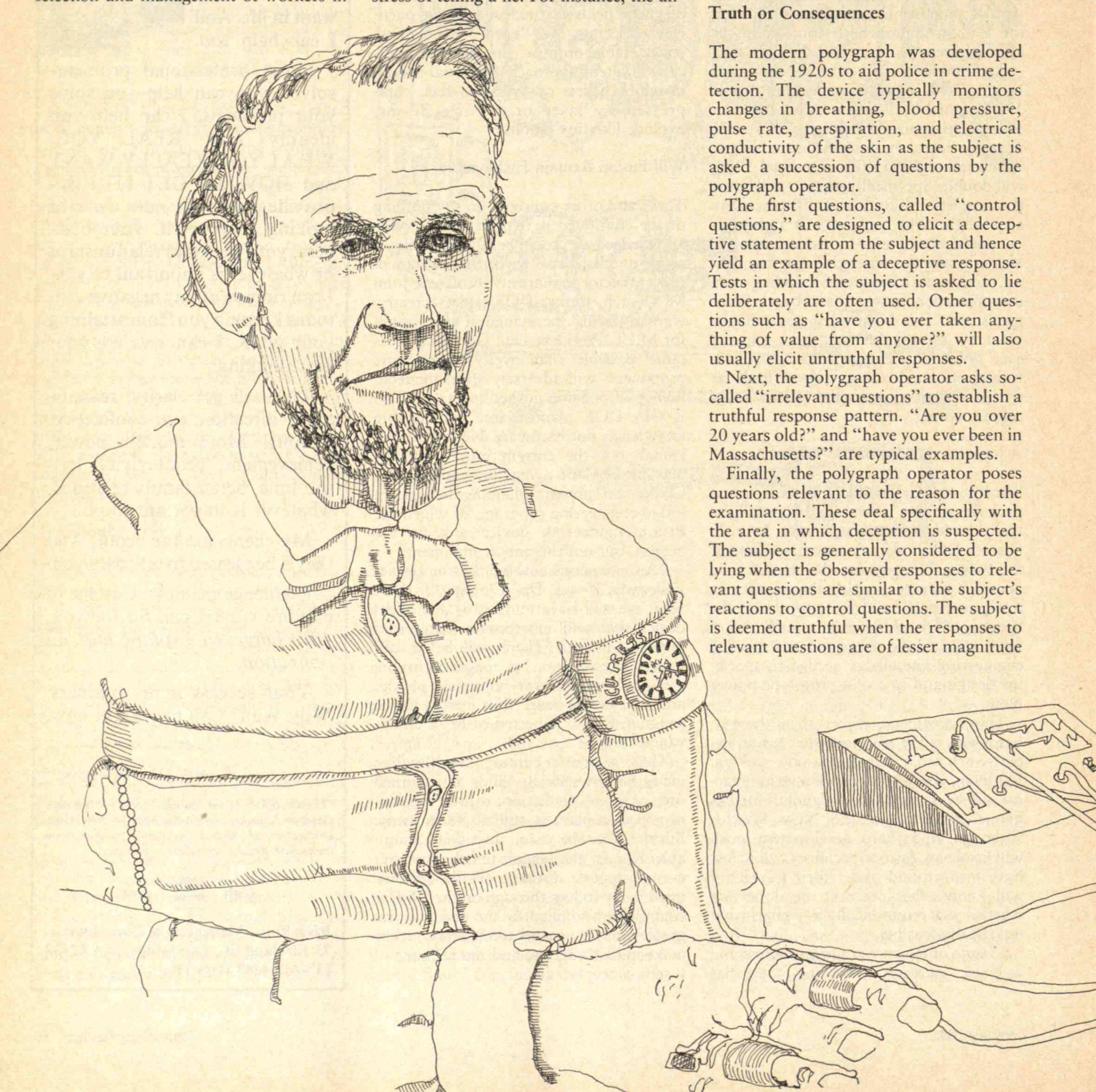
Truth or Consequences

The modern polygraph was developed during the 1920s to aid police in crime detection. The device typically monitors changes in breathing, blood pressure, pulse rate, perspiration, and electrical conductivity of the skin as the subject is asked a succession of questions by the polygraph operator.

The first questions, called "control questions," are designed to elicit a deceptive statement from the subject and hence yield an example of a deceptive response. Tests in which the subject is asked to lie deliberately are often used. Other questions such as "have you ever taken anything of value from anyone?" will also usually elicit untruthful responses.

Next, the polygraph operator asks so-called "irrelevant questions" to establish a truthful response pattern. "Are you over 20 years old?" and "have you ever been in Massachusetts?" are typical examples.

Finally, the polygraph operator poses questions relevant to the reason for the examination. These deal specifically with the area in which deception is suspected. The subject is generally considered to be lying when the observed responses to relevant questions are similar to the subject's reactions to control questions. The subject is deemed truthful when the responses to relevant questions are of lesser magnitude



than those to control questions, and when the pattern of reaction resembles truthful responses to irrelevant questions.

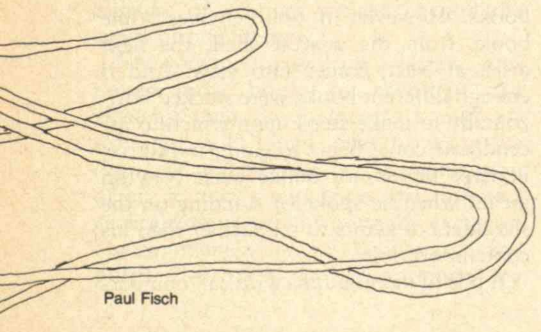
Lie-detection experts claim the polygraph is very accurate. Recent studies found that when a qualified examiner using proper questioning techniques gave the test, the lie detector was 70 to 90 percent accurate.

However, critics of the polygraph say the machine is less accurate and, in fact, has a higher failure rate when the person being questioned is honest. Polygraph instruments do not measure physiological states that accompany lying specifically, but rather physiological changes generated by all kinds of emotional stress. Fear, guilt, anger, physical conditions such as heart trouble, headache, and fatigue, and even tension created by the test itself can all distort the accuracy of the polygraph. In addition, the operator may be inadequately trained, and improper questioning methods or interpretation of measured responses may result in misleading test results.

To Catch a Thief?

A 1978 survey indicated that one-fifth of major corporations were then using the polygraph in personnel-related areas, generally to screen a sampling of applicants or employees. The three industries that appear to use the polygraph most frequently are retailers, commercial banks, and transportation companies.

The polygraph has become attractive to private industry because it is fast and cheap, typically costing under $50 per test compared with about $300 for more conventional methods of background checks. Employers use the polygraph primarily to curb employee theft — retail outlets lose some $20 billion per year to employee pilferage. Polygraphs are also used to verify employment applications and to assess periodically employee honesty, loyalty, and adherence to company policy.



Paul Fisch

Polygraph opponents argue that this method of employment testing is a grave and socially unacceptable invasion of individual privacy. Indeed, polygraph testing often forces a subject to reveal information of a sensitive and personal nature not particularly relevant to the employment situation. A 1974 study found, for example, that the following questions were asked on standard preemployment tests: Have you ever been questioned in connection with a felony? Do you have any lawsuits pending against you? Do you owe more debts than you indicated on your application? Do you drink, take drugs, or gamble excessively? Is there anything in your background that, if known, would cause embarrassment to the company? Companies have also been known to question employees about their sex life, political activities, and involvement with labor unions.

Opponents also argue that the polygraph is an inappropriate device for screening prospective employees because it is designed to obtain a response to a specific past incident. Such a focus is justified for criminal investigations but is entirely inappropriate in the context of future employee conduct. Polygraphy has only marginal utility for broadly predictive purposes such as determining whether an individual is suited for a particular position, and it is hardly a reliable means of forecasting an individual's industriousness or dependability.

Labor arbitration has had the greatest impact on the use of the lie detector in employment, where some employers have sought in vain to win approval for its use in investigating employee misconduct. Organized labor has unequivocally condemned the use of polygraph equipment. A 1965 executive resolution of the AFL-CIO declares: "We object to the use of these devices not only because their claims to reliability are dubious, but because they infringe on the fundamental rights of American citizens to personal privacy. Neither the government nor private employers should be permitted to engage in this sort of police-state surveillance of the lives of individual citizens." The Retail Clerks International Union and other labor unions include in their contracts a prohibition against polygraph tests.

Government concern over polygraph use is gradually increasing. By 1976, 18 states had enacted legislation requiring the licensing of polygraph operators. These laws generally provide character and training standards for examiners and prohibit unethical or improper practices. They also mandate special boards of examiners to issue additional regulations. Critics of the polygraph oppose licensing, however, contending that by licensing polygraph operators, the state implicitly sanctions the use of the machine.

Many states now have laws limiting or prohibiting the use of polygraphs for employment purposes. But nearly all these states exempt law-enforcement personnel and/or government employees from such protection. The laws are not strictly enforced, nor are the penalties for employers who commit violations particularly severe. The penalty for using a polygraph is $200 in Rhode Island and Massachusetts, one year in prison and $1,000 in Alaska and Hawaii.

Because of the invasion-of-privacy issue, the U.S. Privacy Protection Study Commission has called for federal laws that would prohibit the use of polygraphs and other lie-detection devices in employment. To this end, Senator Birch Bayh introduced the Polygraph Control and Civil Liberties Protection Act, which would prohibit the use of polygraphs and similar lie detectors in employment and impose a fine of up to $1,000 and one year in prison for a willful violation. But the defeats of Senator Bayh and other liberals in the elections could stall legislation.

As a matter of sound business management, an employer should be able to hire trustworthy people. But the use of a machine to "detect" lies is, arguably, inappropriate and impractical. More seriously, it violates our society's cherished ideals of individual privacy and civil liberties. As former Senator Sam Ervin opined in 1974, "If the right to privacy means anything at all in our society, it means that people are entitled to have thoughts, hopes, desires, and dreams that are beyond the grasping reach of a bureaucrat, an employer, or an electronic technician." □

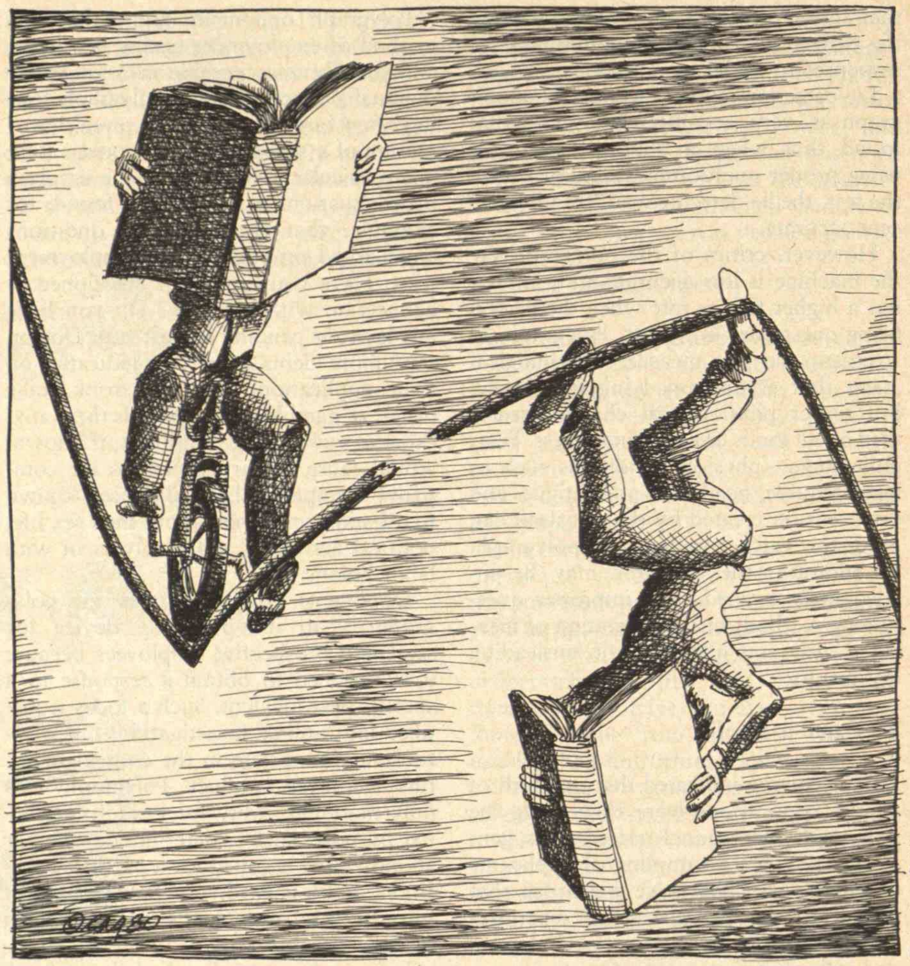
Eric Matusewitch holds a master's degree in political science from the City University of New York. From 1976 to 1980, he was an equal-opportunity employment specialist for the N.Y.C. Human Rights Commission and Health Department.

Of Two Libraries

by Henry Petroski

I am a regular patron of two libraries: a highly technical one at the research laboratory where I work, and the public library of the village in which I reside. For years I have browsed among the shelves of these libraries, often visiting one during lunchtime and the other after dinner that evening, and I have been struck repeatedly by the infinitesimal overlap in their collections.

This and other contrasting characteristics of the two libraries constantly remind me not only of the divergent objectives of the scientific and secular communities but also of the isolation of specialists. The libraries further symbolize the obstacles that must be overcome for communication to exist between scientist and citizen, or even among scientists themselves.



Richard A. Goldberg

Decimal Places

As if to emphasize these differences, the laboratory's technical library uses the alphanumeric system of the Library of Congress to classify its books, while the public library employs the Dewey Decimal System, with which I grew up. Although I lived through the trauma of using the great library at The University of Texas at Austin while it was converting its 3 million volumes from one system to the other, I still have a difficult time recalling conversions like 514.22 = QA612.19. So, in the spirit of metrication, I will use the decimal system here.

The collection of a typical technical library is likely to be catalogued under only two of the ten major classes of the Dewey system, the 500s and 600s, which contain the pure and applied sciences, respectively. The collection of a public library, on the other hand, spans the classification spectrum from 001 to 999 and goes beyond it by throwing in a massive amount of creative writing, usually under the numberless designation *F*, for fiction.

Technical libraries can thus be thought to stress detail by amassing information to more and more decimal places, while the general library is more interested in providing grosser, order-of-magnitude approximations. It also provides, through fiction and its poetic relatives, a view of the world that is qualitative rather than quantitative, subjective rather than objective.

The scientists and engineers at my laboratory continually demand more and more specialized literature: esoteric monographs and obscure journals with press runs in the hundreds, and proceedings of international meetings that involve no more than 50 specialists. Its users are so specialized that the laboratory's library system is actually composed of ten branch libraries altogether serving fewer than 2 thousand scientists and engineers.

Each branch library concentrates on a narrow discipline such as chemical engineering (the Dewey 660s) or high-energy physics (principally the 530s). The branches are generally located in the same buildings as their users, and thus there is little need for, say, a chemical engineer to leave the chemical-engineering building except to go to lunch at the cafeteria — usually to sit at a table of chemical engineers. Such isolation was probably not intentional, but it is one of the effects of the system of branch libraries.

Imagine that one could gaze through the roofs of the laboratory buildings that house the separate branches of the library. From this vantage point one would see several separate labyrinths of book stacks. One also would observe physicists and chemists, mathematicians and engineers, navigating through mazes of shelving to track down obscure references to other references. The researchers' paths would seldom cross. If they were not in separate buildings, they would be in separate aisles, looking at the world with blinders — the monographs of their various specialties.

Even in a public library, one's line of sight is channeled between the stacks, and it can be difficult to see the library for the books. However, if one removes some books from the nearest shelf, the next aisle, at least, comes into view. And if enough different books were stacked horizontally to make steps upon which to ascend, one could begin to gain perspective. Perhaps this is not unlike what Newton meant when he spoke of standing on the shoulders of giants to see farther than his contemporaries.

A pile of monographs with call numbers

identical to the fifth Dewey decimal place does not reach very high, however, and the specialist who stands upon it can barely see over the topmost shelf of one special aisle of one special library. Only those scientists browsing nearby will see their colleague standing on the monographs. To colleagues two aisles away, he or she may as well be out to lunch.

Most citizens do not need a research library, let alone a branch research library. They use local public libraries, where fact and fiction, science and poetry, are never shelved very far apart. Dewey's continuum is housed under one roof and a reader can move freely from art to philosophy to sociology to science and technology. There are no monographs to stand upon or to conceal and separate one aspect of life from another.

One Is Not Enough

When the time comes for public discussion of broad, complex issues such as energy policy, the differences between public and research libraries exacerbate misunderstandings and complicate the debate. Whereas the specialists, who after all will be called upon to effect technological fixes, are well read in the narrow, technical aspects of a problem, the public is often more familiar with broader aspects of the issue. Reconciling the different points of view — referencing fairly the two libraries — is one of the most difficult tasks of our time.

Newton is reported to have said near the end of his life that he seemed to have been like a mere boy, playing on the seashore and diverting himself now and then by finding a smoother pebble or a prettier shell than ordinary, while the great ocean of truth lay undiscovered before him. The smoother pebble or prettier shell might also have been a finer monograph or a fairer poem, and the ocean a library. Who among us has not been elated at finding a gem of a book in the library? And who has not been humbled by the expanse of volumes shelved beyond the spans of our lifetimes?

Yet Newton, whose own library contained more books on theology and alchemy than on mathematics and astronomy, still found time to write his *Principia* and oversee the reorganization of his country's mint. Specialization and generalization are not mutually exclusive but complementary, just as research and public libraries are complementary sources of information and inspiration.

The books we need for writing a successful proposal for the future are not found strictly in one or the other kind of library. Authors of truly successful proposals will surely consult books from both, for neither alone has all the answers. □

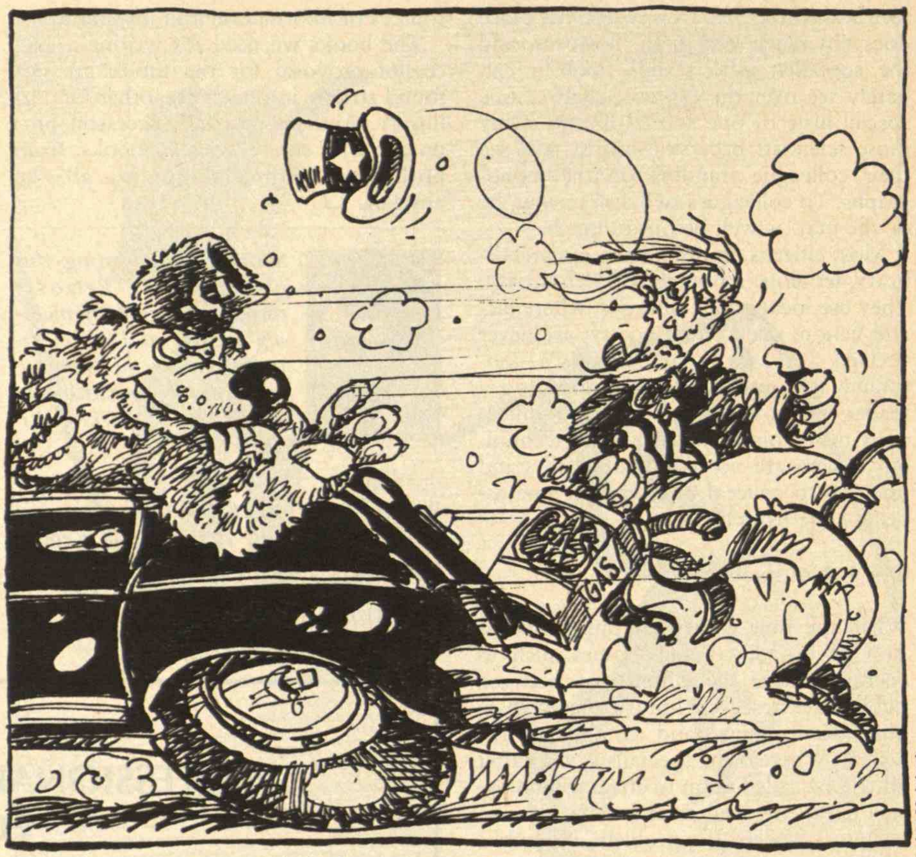
Shortly after writing this piece, Henry Petroski joined the civil engineering faculty at Duke University, where he is enjoying both the breadth and depth of the Perkins Library.

We welcome contributions from our readers to Forum and Special Report. Queries should be submitted to the Forum editor, Technology Review, Room 10-140, M.I.T., Cambridge, MA 02139.

Russia's Energy Resources: So Near and Yet So Far

The Soviet Energy System
Leslie Dienes and Theodore Shabad
New York: Halstead Press, 1979, $19.95
Science and Industrialization in the USSR
Robert Lewis
New York: Holmes and Meier, 1979, $30

Reviewed by Thane Gustafson



Jon McIntosh

A lively debate is going on over reports that the Soviet Union, currently the world's largest producer of oil and its third largest exporter, faces an imminent leveling off and quite possibly a decline in oil output. There is nervous speculation that the Soviet bloc may soon depend on oil imports, which would put further pressure on energy prices around the world. Worse yet, some suggest that, attracted by the possibility of satisfying both their strategic ambitions and oil needs, the Russians may cast a greedy eye on the Persian Gulf.

Dienes and Shabad show with a wealth of evidence that the Soviet energy problem is, in several respects, a mirror image of that of the West. The immediate source of Soviet difficulties is an unexpectedly sudden decline in growth rates of oil output and discoveries of new fields in Western Siberia. However, unlike the United States, the Soviet Union does not compete with its allies for energy; it supplies them. The problem is temporary: beyond a tough decade in the 1980s, the Soviets stand the closest to true energy independence of any industrial power.

Dienes and Shabad argue that the Soviet energy economy has been, on the whole, competently and rationally developed. For example, the Soviets have resorted to widespread use of cogeneration to provide both electricity and heat, and they were one of the first to electrify their railroads. Why then do the Soviets now find themselves in such deep trouble?

Part of the reason is overdependence on oil, the result of the same rapid response to low oil prices that took place all over the world following World War II. The Soviets converted from coal to liquid fuel for electricity generation far more completely than the Americans, and consequently must switch back.

But the Soviets' special difficulty is that their vast energy supplies are far from the main industrial and residential centers, principally in the frozen tundra of Western Siberia, where severe natural conditions discourage immigration, retard exploration and development, and send costs sky-high. Basically, the Soviets have less an energy problem than a problem in regional development and transportation.

Tough Decisions

The impending Soviet oil shortage is largely due to inadequate exploration complicated by an inordinate optimism in enhanced oil recovery. The task of devising and implementing a solution is made more difficult by weaknesses in the Soviet political and administrative system. Nevertheless, the current energy problem should be the sort of dilemma that the Soviet system is especially well equipped to handle. After all, at least on the production side, energy development seems to call for precisely the kind of all-out mobilization of resources that the campaign-style Soviet system handles best. However, Dienes and Shabad show that in reality the Soviets face a much more complex challenge, one that will require fundamental choices as great as any since the command industrialization of the 1920s and 1930s.

These decisions are of two sorts. First, the Soviet leadership will have to decide which of its major potential energy sources to develop first, or more exactly, what mix to strive for. Oil is the most tempting because of the phenomenal performance of the Western Siberian oil fields during the 1970s. But there have been no new giant oil fields discovered there since 1974, and given the difficulty of exploration and the backwardness of Soviet exploration technology, it would be foolhardy to risk everything on the chance of discovering another supergiant soon.

Coal is undoubtedly a major part of any Soviet energy equation, but the sources next in line for development (located in Ekibastuz and Kansk-Achinsk) consist of lignites of uneven quality, high ash and low heat content, and tricky handling properties. Thus, major engineering developments will be necessary simply to burn this coal, let alone to ship it more than a thousand miles away.

Nuclear power is likewise indispensable, especially since, of all the major energy sources, it alone can be concentrated near points of demand. The Soviet Council on Mutual Economic Assistance program for the 1980s calls for the construction of as much as 37 gigawatts of new capacity, to be built jointly inside and outside Soviet borders, to supply electricity to Eastern Europe. Soviet planners hope this will replace as much as half the present Soviet fuel exports there. However, Dienes and Shabad observe that the current five-year nuclear program has suffered from major delays, and the Soviet Union may not be able to meet such an ambitious schedule in addition to its own plans for nuclear power.

Soviet gas reserves in northern Western Siberia are prodigious and reasonably well explored. Developing the fields and shipping the gas to European Russia, however, are enormous tasks. To add 100 billion cubic meters of West Siberian gas every two or three years during the 1980s, the Soviets would have to increase their output of rolled steel by one-third by 1990. But an even more serious obstacle is the lack of infrastructure (roads, housing, and electrical power) in the gas-producing areas. Already Urergoy, the largest gas field, is running behind schedule.

Whatever mix of energy sources is finally adopted will require substantial technological innovation, and Soviet leaders will face a second array of fundamental choices. For example, the poor quality and remote location of new coal sources will require advanced techniques for long-distance high-voltage transmission of electricity, in addition to special combustion techniques and strip-mining machinery. Other fuel sources are only slightly less daunting in their research-and-development requirements. These involve improving the manufacture and installation of pipelines and intermediate pumping stations for natural gas; developing new types of peak-coverage equipment such as pumped-storage hydropower, gas turbines, or nuclear power plants that can be operated in a variable mode; increasing the efficiency of oil exploration-and-development technology (particularly for drilling); and adjusting the product mix of Soviet refineries toward lighter fractions.

These requirements impose a basic choice between near-term and long-term strategies. A short-term coping strategy might consist of continuing the present policy of forced oil output for three or four years (at the price of a considerably steeper decline later), while rapidly expanding oil exploration in Western Siberia with additional drilling. Also included could be a crash program to increase pipeline construction, intensified coal mining in developed areas such as the Kuzbas, and accelerated construction of nuclear power plants. But such a plan would have to produce results by the mid-1980s, and would necessitate turning to Eastern Europe and the West for large infusions of skilled labor, credits (hard currency and bank loans), and technology.

A long-term strategy, on the other hand, would call for cutting back oil slightly now (thus hoping to lengthen the lifetimes of existing fields), imposing limits on consumption, and concentrating on domestic research and development to solve basic problems.

The Repetition of History

Such choices have been issues in Soviet investment policy since the start of the Soviet era. Robert Lewis's brief history, *Science and Industrialization in the USSR*, takes us back to the 1920s and 1930s, when the fundamental choices involved in promoting rapid development were raised for perhaps the first time by any central government. However much the scale and sophistication of Soviet science and technology have changed, the basic questions have not. Then, as now, the Soviet press criticized industrial ministries for neglecting research and innovation. Then, as now, the Soviets experimented with varying degrees of centralization in R&D management. The question of how much to displace native invention with foreign technology was also important.

Over the last half-century, the context of Soviet technology policy has changed. Why then are the issues currently being debated by the Soviets in R&D policy so similar to those of 60 years ago?

Professor Lewis touches on two possible hypotheses. The first is that Soviet problems in technology stem directly from the mode of organization chosen in the 1920s, which has remained largely unchanged. The other hypothesis is that the organization of R&D matters less than the organization of the underlying economic system, which has resulted in a chronic resistance to innovation in all but the highest-priority sectors. Unfortunately, Professor Lewis addresses these questions only in the last few pages, thereby weakening his otherwise well-researched account.

Traditionally, certain branches of Soviet technology have been given high priority, allowing the Soviets to be successful in producing advanced technologies without overt dependence on foreign help. Robert Lewis shows how this was done in the aircraft industry, one of the most impressive Soviet success stories, by balancing political priority with innovative management. One of the most important questions of today, however, is whether the management devices developed for the high-priority zone can also work outside it.

The energy sector got a mixture of treatments. Electric power was given particular attention, which may help explain why it is now the most advanced Soviet energy technology. The current excellence of Soviet nuclear power is undoubtedly due to its location at the juncture of two-high priority operations, the electrical and defense industries. The weakness of innovation in the other Soviet energy sectors — oil, coal, and gas — may be due less to low priority than to the lack of need, until recently, for better technology. Oil exploration and development in particular appear to be remarkably inefficient. Does it follow, however, that once an energy priority is designated, Soviet technology will be able to rise rapidly to the occasion? Nothing is less certain.

Lewis's account suggests another possibility: once the pressure for fast results passes a critical point, near-term concerns may drive out the long-term. This happened at the end of the 1920s. Most scientists were given neither the time nor the leisure for domestic technological innovation in the campaign atmosphere of the first five-year plans.

But today's leaders do not have the option of responding in Stalin's extreme fashion. In the 1930s, planned development involved mobilizing mass enthusiasm and fear to execute a relatively small number of tasks. Now Soviet success in the energy sector depends on managing rapidly growing scarcity and complexity; bringing together an increasingly independent labor force and inaccessible resources; increasing the carrying capacity, sophistication, and efficiency of energy transportation; and finding ways of altering the energy-wasteful behavior of local decision makers. The Soviet energy problem, and particularly the technological choices arising out of it, tests the adaptive capacities of their entire political system.

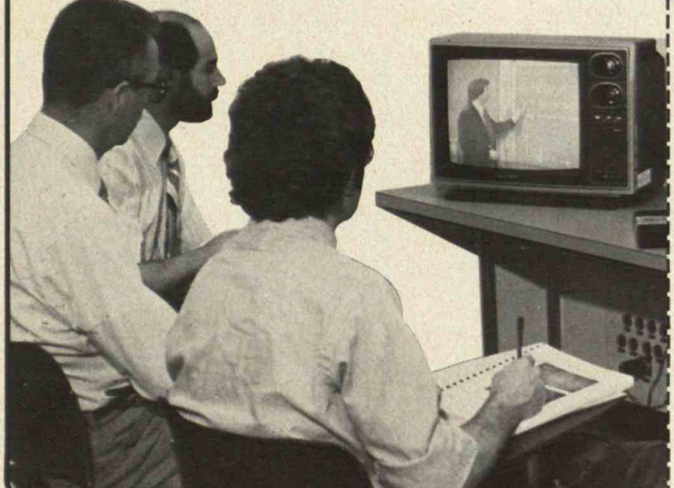
Reform or Import and Improvise?

In setting priorities among competing energy sources, the Soviet leadership has been uncertain. During the first half of the 1970s, official policy stressed the development of coal resources. Then, in late 1977, the leadership opted instead for a crash program to develop Western Siberian oil. This was followed by a partial return last year to a more balanced policy in which gas and nuclear power have replaced coal as primary candidates for expansion. Is this vacillation the result of pressures by various interest groups? Or is the central leadership gradually coming to grips with the full implications of a complex problem?

We can follow the evolution of leaders' preferences for short-term and long-term policy by observing their choices in technology policy. A major effort to improve native energy technology would require a corresponding effort to deal with the chronic problems hindering innovation, either by giving energy higher political priority (as in the defense sector) or by promoting management reforms. But can high political priority, the scarcest of resources, be stretched to include the energy sector? Lewis reminds us that the historical Soviet response to management problems has been to redraw the organizational chart and hope for the best. Will the current Soviet political elite, which has shown no stomach for major reform in the last 15 years, have the imagination and decisiveness to depart from the historical pattern in the next decade? They may see it as easier and surer to turn to Western Europe for help, thus strengthening a growing Soviet-West European community of interest in energy matters.

Despite a difficult decade ahead, however, Soviet energy resources will ultimately be abundant. The long-term danger is not that the Soviets may plunge toward the Persian Gulf, but that they will almost certainly use their untapped energy riches as powerful levers in Western Europe.

Thane Gustafson, former professor of political science at Harvard, is presently research associate in the Social Science Department at the Rand Corp. □



Ralph Mercer

World Uranium: Softening Markets and Rising Security

by Thomas L. Neff and Henry D. Jacoby

THE behavior of the international uranium market is of great interest to any nation depending on nuclear power for a significant share of its future energy. These countries' concerns involve not only price but the adequacy of supply and security of access in the long-term future. Thus, like energy generally, uranium has become a strategic commodity for reasons of national economic security. But there is an additional security problem unique to uranium, deriving from its connection to nuclear weapons proliferation. The low-enriched uranium fuel used in most contemporary reactors does not directly make possible the proliferation of nuclear arms. But its availability may affect national decisions on more sensitive technological steps, such as the recovery of plutonium from spent fuel or the enrichment of uranium into reactor fuel.

There is sharp controversy over the relationship of fuel supply to proliferation risk. Some argue that strictly enforced restrictions on fuel supply (such as the U.S. requirement of wide-ranging safeguards on nuclear material or prior approval of its customers' technological decisions) are the only way to assure that consuming nations will not obtain nuclear weapons from spent reactor fuel or from uranium itself. Others hold that such restrictions on supply only aggravate worries about energy security, driving nations to develop their own uranium processing and reprocessing capacity and thus make the very commitments that nonproliferation policies are de-

The international uranium market will offer supplies in substantial excess of demand at least through the 1980s and probably well beyond, challenging the viability of the U.S. uranium industry and many countries' nonproliferation policies.

Like energy generally, uranium has become a strategic commodity for reasons of national economic security.

signed to avoid. This debate has led some suppliers to impose various (and frequently retroactive) constraints on uranium or fuel-cycle services, thus creating political uncertainties that have added to general world concern about conditions in the uranium market.

These security-related political issues are more critical if the uranium market is tight, or if there is little flexibility in supply arrangements. Conversely, the existence of an excess of supply from a diversity of sources lessens the impact of political constraints. But perceptions of security problems do not always match reality. No doubt political disruptions have in the past coincided with tight conditions in the uranium market, resulting in justifiable concern. But such experiences may have a residual effect on expectations about future supply even after conditions have changed. Fearing a return of tight supplies and political pressures, consumers may be led to actions that are economically wasteful — and perhaps costly from a political perspective as well.

An important factor contributing to volatility in the uranium market is the poor quality of information about current events in the uranium industry. The commercial uranium market is relatively new, and the industry is extremely secretive; producers and consumers do not ordinarily disclose quantities or prices of imports and exports, or information on their origin and destination. For these reasons, industrywide data collection and reporting services are immature; and when little is known, it often is prudent to assume the worst.

A clearer view of the international uranium market can help reduce this volatility and relieve at least some of the security concerns of consumer nations. Hence, the International Energy Studies Group of the M.I.T. Energy Laboratory has undertaken one of the first efforts in the public domain to clarify the present and future situation of the international uranium market. We have studied trade flows, data on export and import contracts, and current expansion plans for reactors and uranium mines. The result is a global view of uranium trade, general supply-and-demand balances, and worldwide stockpiles.

Our analysis suggests that much of the current anxiety about future uranium supply results from a brief-but-difficult period in the mid- to late-1970s, and that current conditions and trends are so favorable (at least to consumers) that there is little basis for worry about supply during the next 10 to 20 years. When compared with realistic (or even unrealistic) demand estimates, today's inventories, contract positions, and producer commitments imply a buyers' market for at least the next decade. The market will have growing flexibility and resilience to shock, and prices (in constant dollars) will be considerably below those of the past few years.

World Trade Patterns in Uranium

In studying the supply side of the market, we have concentrated on five principal net exporters: Australia, Canada, South Africa, Namibia, and Niger. They supply virtually all the world's uranium outside the United States and the centrally planned economies of Eastern Europe. Though new sources are being developed in Spain, Brazil, and elsewhere, it is unlikely that these nations will contribute significantly to uranium trade over the next decade or so.

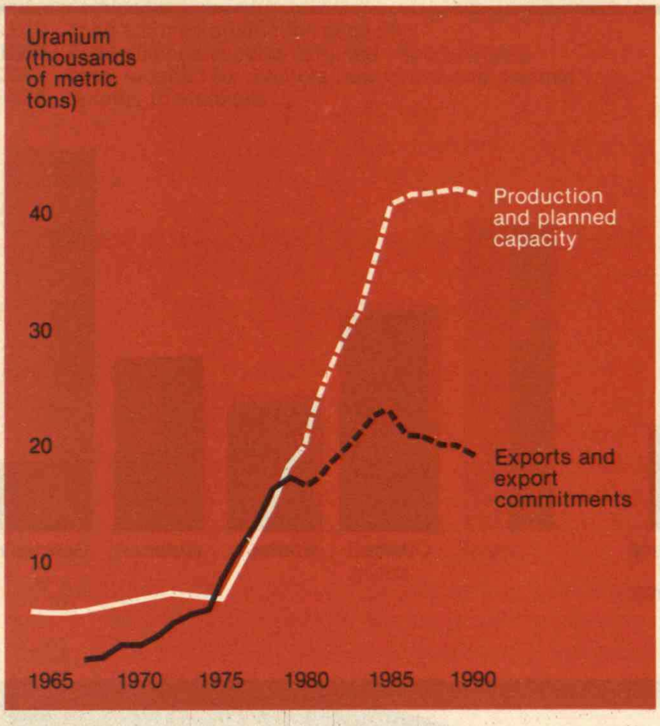
Among the consumers, we focused on Japan, France, and West Germany — countries that together account for 76 percent of all identified international uranium commitments between 1968 and 1990. The rest of the world's consumers are combined into an "others" category. The United States is included in this group as a net buyer because, despite the large size of the U.S. uranium industry, there is only a small trade in uranium ore between the United States and the world market.

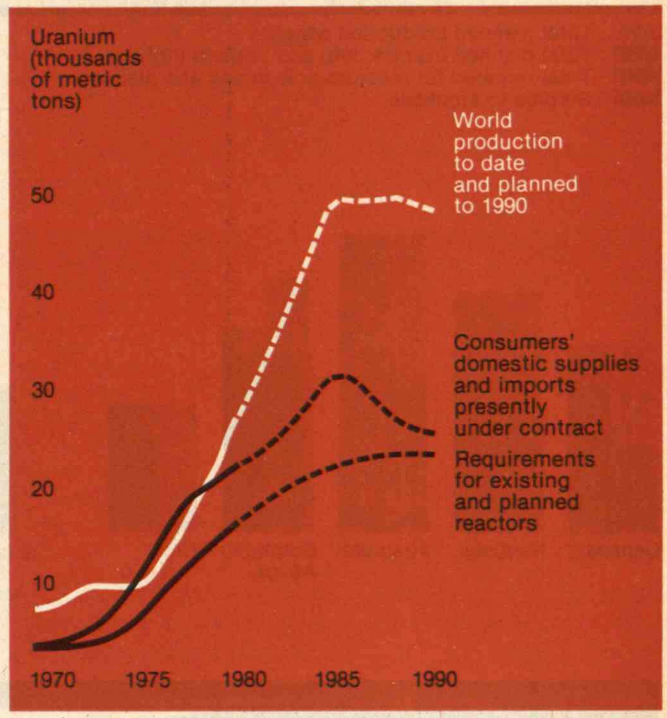
Our analysis of the market begins with our estimate of current uranium production and international trade patterns, shown in the chart on page 22. In 1980, the export commitments of Canada, South Africa, and Niger were smaller than planned production, so these producers added to inventory that year. Indeed, a significant fraction — about 35 percent — of total 1980 production, including small producers not shown (a total of about 8,500 tons of uranium), went into inventories somewhere in the system. (The unit used throughout this article is the metric ton of uranium metal, equivalent to 1,000 kilograms or 2,205 pounds.) In contrast, Australia drew on inventories in 1980 to meet contract commitments.

Japan contracted for supplies greatly in excess of reactor needs in 1980, resulting in a net addition to its inventories. Supplies contracted for by France, Germany, and the "other" group (excluding the

Left: The surplus position of the five primary exporters of uranium: Australia, Canada, Namibia, Niger, and South Africa. For nearly four years late in the 1970s, industry drew on inventories when production capacity proved inadequate to meet a sudden surge in demand. But fears of shortages in some developed countries that rely heavily on nuclear power were never realized because of rapid increases in production and reduced nuclear power plant construction.

Right: Total present and prospective world uranium supply under current contracts compared with requirements (not including the U.S. and Communist-bloc nations). Reactor requirements cannot increase before the late 1980s, and cancelations and delays are likely to reduce it. But supply, already projected to exceed requirements throughout the 1980s, could be substantially increased by additional planned production capacity.





U.S.) were only slightly in excess of reactor requirements.

Several interesting aspects of today's uranium trade emerge. West Germany and Japan are very well diversified in their uranium sources, whereas France depends heavily on sources from her former African colonies (Gabon and Niger) and South Africa. France plays an important role in the market for two reasons: its total volume of uranium trade is large, and there are commercial connections between France and several other nations on both the supply and consumer sides. In effect, the French network represents a separate submarket, though France has made very few new export commitments since 1974.

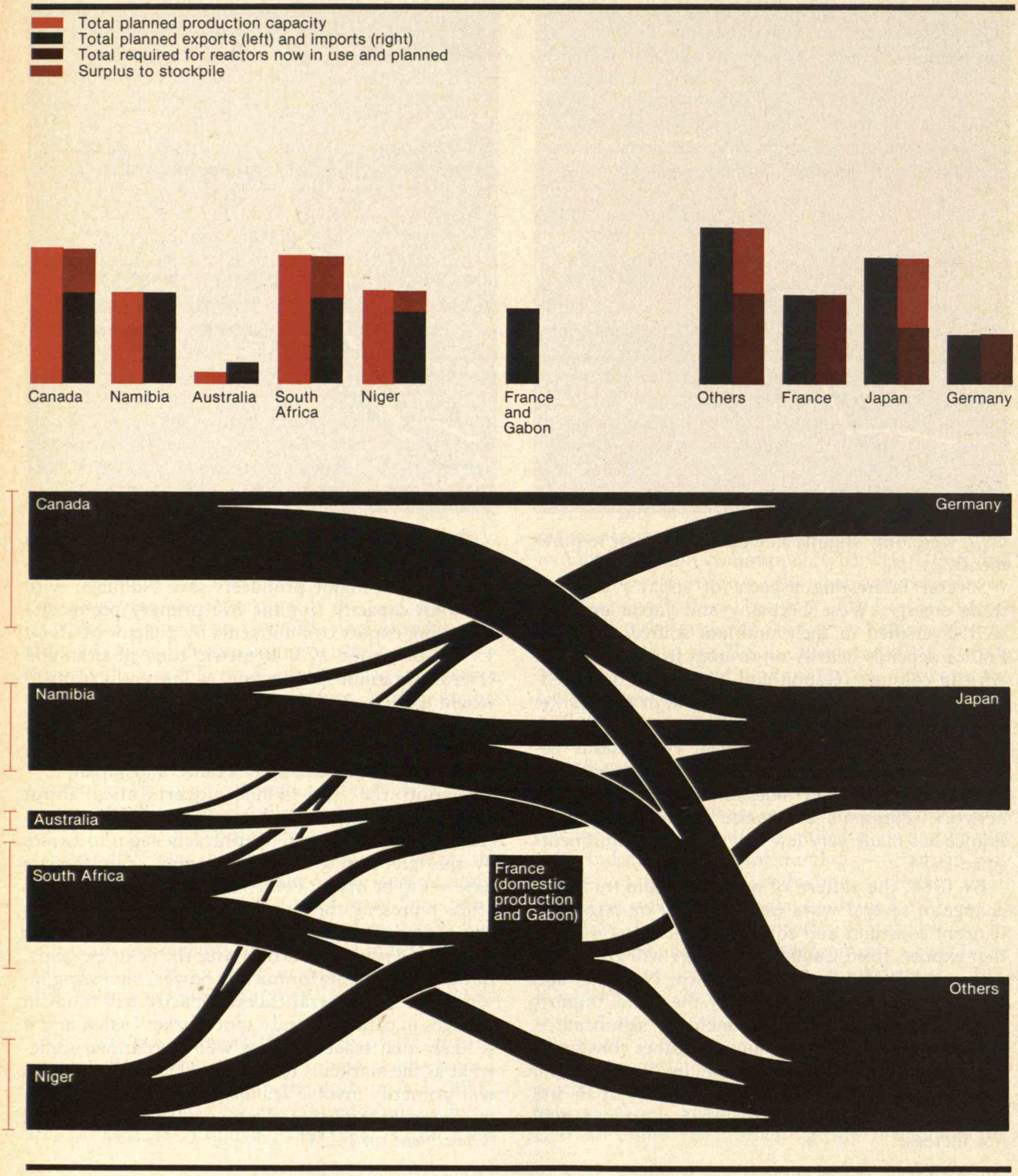
By 1985, the pattern of world uranium trade will change in several ways (*see the chart on page 23).* Current contracts and equity arrangements indicate that exports from Canada and Niger will greatly increase, while those of South Africa, Namibia, and Australia will remain essentially the same. Imports by Japan and France will increase significantly, while those of West Germany and other consumers will not. That is, the increase in exports from Canada and Niger will go primarily to Japan and France. French reexports to other consumers will not increase.

The chart reveals that by 1985, production capacity now planned will exceed export commitments for all major producers save Namibia, with the total capacity (for the five primary producers) exceeding export commitments by a factor of about 1.7 — or about 17,000 metric tons of uranium. Overall, uranium production as currently planned would exceed world reactor requirements in 1985 by more than 100 percent, or about 24,000 metric tons, with about 7,000 metric tons added to consumer stocks, principally in France and Japan.

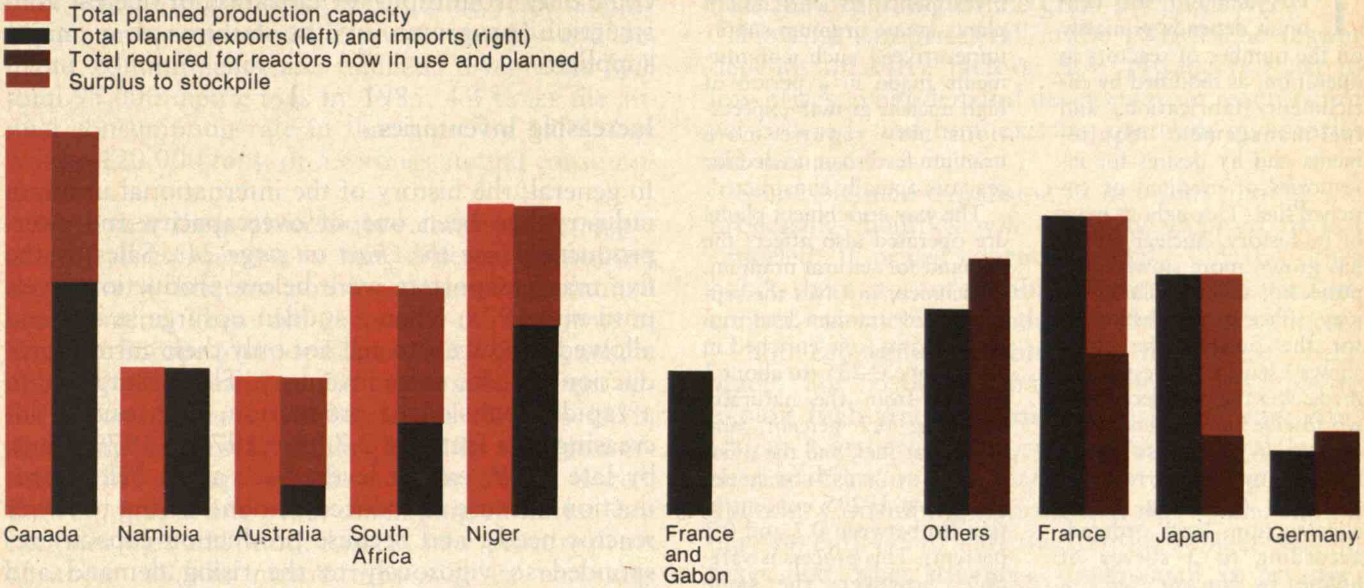
Beyond the mid-1980s, uncertainties about uranium production and reactor requirements increase. Moreover, current contracts begin to expire by the late 1980s, and new supply arrangements have yet to be made. These "snapshots" of 1980 and 1985 represent the implications of existing plans and contracts; they give an approximate picture of how world trade will evolve over the next few years. But changing plans for nuclear power, increasing inventories, and general excess capacity will result in changes in contracts and "spot market" sales, and it is likely that trade patterns will be redrawn somewhat as the market is rebalanced. These adjustments will primarily involve reallocations and cutbacks in purchases; significant tightening of the market could

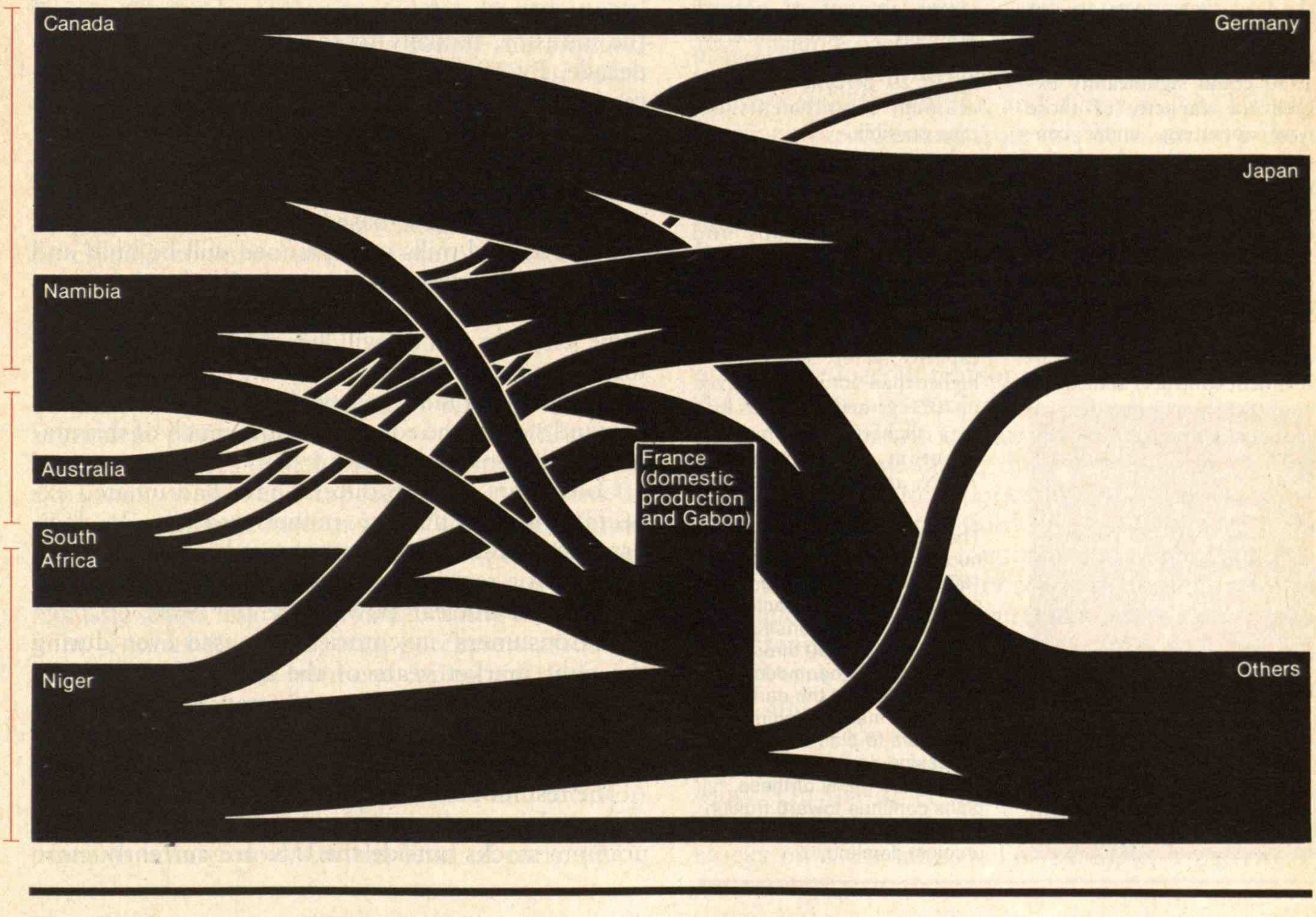
(Continued on p. 24)

The pattern of world uranium flow from producers (*left*) to consumers (*right*) in 1980. Canada, Namibia, Australia, South Africa, and Niger were the world's largest uranium exporters last year, with Japan, Germany, and other Western European nations the largest importers. France, simultaneously producer (including its former colony, Gabon), consumer, and exporter, is shown in the middle. The width of the channels is proportional to the quantity of uranium. The bars at the left indicate the production capacity of each exporting nation (in the case of Canada, the bar shows the net capacity available for export after the needs of domestic reactors are met). This excess capacity over exports is one measure of the world uranium surplus revealed by this study. The bars on the right indicate reactor requirements in the importing countries, where some building of inventories is also evident.



Projected 1985 world uranium trade. Increased export contracts (over 1980) from Canada and Niger preferentially go to Japan and France, in quantities greatly in excess of planned reactor requirements. Uranium production capacity of all the exporting nations will increase substantially between 1980 and 1985, and potential supply will be significantly higher than demand, even if the latter includes considerable stockpiling. Since this figure was drawn, Australia has arranged sales totalling about 2,300 tons for 1985 (including 1,200 to West Germany). Under recent contracts, Canadian exports will increase by an additional 700 to 1,000 tons in 1985, and South Africa has reportedly found alternative buyers for some of the uranium originally destined for Iran.





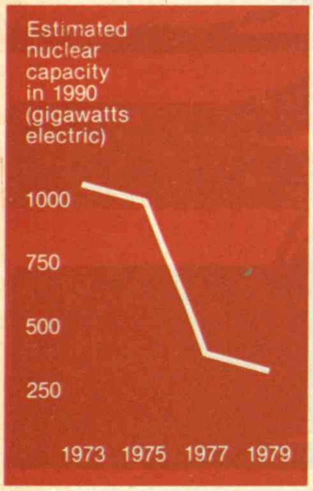
Uranium Demand

THE demand for uranium depends primarily on the number of reactors in operation, as modified by enrichment, fabrication, and fuel-management requirements and by desires for inventories of uranium or enriched fuel. Throughout most of its history, nuclear power has grown more slowly than projected, and a similar effect may afflict current estimates for the future. The chart shows a sequence of estimates made over the past decade for worldwide nuclear generating capacity in 1990. Also shown is the number of reactors presently operating, under construction, and ordered, according to a survey of utilities by *Nuclear News*, a publication of the American Nuclear Society. Because of the lead times necessary for building reactors, it is unlikely that reactor capacity in 1990 could significantly exceed the capacity of those now operating, under construction, and ordered; indeed, cancelations have recently outnumbered new orders.

High expectations of growth in nuclear power have led to large procurement commitments for uranium and enrichment services. Enrichment contracts and equity investments in enrichment plants create uranium supply imperatives: such commitments made in a period of high nuclear growth expectations may require more uranium feed than needed for reactors actually constructed.

The way enrichment plants are operated also affects the demand for natural uranium. Enrichment involves the separation of uranium feed into two streams, one enriched in the isotope U-235 (to about 3 percent from the naturally occurring 0.7 percent) and usable for fuel, and the other a waste or "tails" stream decreased in U-235 concentration (to between 0.2 and 0.3 percent). This process is variable, however: the same amount of fuel can be produced from a smaller or larger amount of natural uranium by using more or less enrichment. Changes of up to 20 percent in natural uranium requirements are thus possible.

In our analysis, we have computed uranium requirements for reactors operating, under construction, and ordered (called "present plans"), assuming 0.2 percent enrichment-plant tails assay and a 70 percent reactor capacity factor. The latter is higher than actually achieved on average and may thus lead to a slight overstatement of uranium requirements.—*T.L.N. and H.D.J* □



The changing visions of our nuclear future. Throughout the 1970s, estimates of the number of nuclear reactors operating, under construction, or on order in 1990 throughout the world have been declining. The optimism of the early 1970s led many uranium producers to plan for increasing demand in the 1980s, and many of these plans continue toward fruition despite the prospect of falling uranium demand.

come only from rapid revitalization of nuclear construction programs or the failure of a major supplier.

Increasing Inventories

In general, the history of the international uranium industry has been one of overcapacity and overproduction (*see the chart on page 21*). Sales by the five major exporters were below production levels until mid-1975, when a sudden upsurge in demand allowed producers to sell not only their current production but also some inventory. This upsurge led to a rapid expansion of production, with output increasing by a factor of 2.7 from 1975 to 1979. Thus, by late 1979, export levels were again below production because of reduced demand owing to lower reactor needs, and because production capacity responded so vigorously to the rising demand and exploding prices of the previous four years.

Our analysis suggests that this period of prosperity was but a brief discontinuity in the experience of the industry, unlikely to recur for at least another decade. By 1990, cumulative production could exceed currently contracted sales by as much as 190,000 metric tons of uranium — more than eight years' supply for (non-U.S.) reactors operating, under construction, or ordered as of 1980. Admittedly, this forecast is based on the assumption that new mines and mills now planned will be built and operated regardless of demand. Obviously, many planned facilities will be delayed and output from some existing mines will be cut back. But many forces lend momentum to current expansion plans, so it is perhaps more reasonable to look first at the demand side of the equation: How much of this material will consumers want to buy?

Consumers, like producers, have had inflated expectations for nuclear power growth. In fact, uranium purchased by consumers has exceeded actual reactor requirements over the entire history of commercial nuclear power (*see the chart on page 21*). Consumers' inventories increased even during the tight market years of the late 1970s, and the uranium supply already contracted for by today's consuming nations exceeds their reactor requirements until 1990 and beyond.

The result of such excess procurement can only be increased inventory, as shown on the chart. World uranium stocks outside the U.S. are currently more

If nuclear power continues on its current path of very modest growth, there will be a continuing downward trend in uranium prices over the next decade.

than 40,000 metric tons, nearly three years' supply for all present reactors. If present supply and demand commitments are fulfilled, inventories will total 95,000 metric tons by 1985, 4.4 times the annual consumption rate in that year. By 1990 they will be 120,000 tons, or 5.6 times annual consumption.

Note that these observations concern the aggregate of all consumers; in fact, different consumers are in very different positions regarding uranium procurement. There are uncovered requirements in Western Europe (outside France and Britain), where about 39,000 metric tons in addition to current delivery commitments will be needed through 1990, according to present utility plans. In the "rest-of-the-world" group, which includes South Korea, Taiwan, Brazil, and other developing countries (but excludes Iran and South Africa), new procurements of about 10,000 metric tons will be necessary through 1990 to fulfill present plans.

Where might these countries with prospective deficits fill their uranium needs through 1990? Obviously, producers could easily supply this amount; indeed, it is likely that Canada, Australia, or South Africa could alone supply the necessary 50,000 metric tons between now and 1990. For the developing countries with lesser individual needs, there are many possibilities among suppliers. And since some of the consumers will also have large inventories, the developing countries may well turn to them, thus creating a secondary trade among consumers.

Prices: A Buyers' Market

Prices will be a major influence on both uranium development plans and the level of stocks during the next two decades. Much of the recent and planned expansion of uranium capacity was stimulated by the tight market conditions and consequent rapid price rise in the mid-1970s, when export commitments slightly exceeded production for several years. A classic sellers' market prevailed during this period: joint ventures expanded, with purchasers assuming a large portion of the front-end capital risk and with price provisions very favorable to exporters.

But the picture has been changing drastically since 1979. Nominal prices have fallen — from the mid-$40 range in 1978 to less than $30 — and the drop in real prices has been striking: the real price for uranium is now down to the level of early 1975, near the beginning of the great price upsurge.

How far can prices fall in the 1980s? The answer depends on three factors: how producers react to low prices, what demand develops from reactors not yet ordered, and how existing uranium inventories are managed.

Some planned expansion in uranium mining and processing facilities will surely be delayed, if not canceled, if prices continue to fall. On the other hand, there is considerable momentum toward increased capacity and production. Major investments — both economic and political — have already been made. For example, roads, mines, and mills to exploit high-grade deposits in Saskatchewan, Australia's Northern Territory, and Niger have already been built, many with loans to be repaid out of production. Consuming nations that put up the capital may be entitled to half the output, subject only to taxes and other royalties. Under such an arrangement, the host government or company is likely to be entitled to sell the other half of the output, and both producer and consumer experience very low unit variable costs. In South Africa, facilities for recovering uranium from ore mined for its gold content are already paid for, and it may well be less expensive to recover and store this uranium now than to dump the gold tailings and recover the uranium later. There are thus economic incentives to produce and sell much of today's uranium even at relatively low prices. In sum, as prices fall, the short-term elasticity of supply may be very low.

Orders for new reactors are a second major factor affecting uranium prices. Some downward pressure could be reduced if reactor construction increases in the next two or three years. However, if nuclear power continues on its current path of very modest growth, as seems likely, there will be a continuing downward pressure on prices over the next decade.

Inventories are the third key factor. As we have seen, a few consumer countries are building huge inventories that will be very costly to hold. For example, under present procurement schedules, Japan and France together could hold as much as 150,000 metric tons of uranium by 1990. Perhaps these nations and their utilities will be willing to maintain these stocks for a decade or more, in the interests of fuel security and long-term price and planning stability. On the other hand, such stability would be costly, and these consumers may bring some of these stocks onto the market. For example, a pattern of

The low-enriched uranium fuel used in most contemporary reactors is not a direct danger to proliferation.

sales, loans, or other agreements could develop among consumers, with material flowing from those with excess to those in need. Our calculations of global uranium stockpiles in the 1980s show that if efficient mechanisms of this type should develop, growing stocks could be maintained by most consumers with *no* purchases beyond current contract commitments before 1990.

Such exchanges among consumers could easily be large enough to accommodate the needs of the developing countries, whose purchases are now projected to be 8,000 metric tons over the decade. Indeed, a single large producer, consumer, or any combination could provide fuel for any or all of these countries, and the same could be true for the countries of Western Europe that have not secured uranium for planned reactors.

Declining Exploration and Development?

It is clear that, unless there is a failure of supply from one or more major exporters, the world uranium market will be soft for quite some time. Producing countries are unlikely to experience significant new demand much before the end of the decade, and even then demand is unlikely to be near producers' capacity. And it is unlikely that demand will exceed the level of current contracts when the latter begin to expire in the late 1980s unless many new reactors are ordered soon.

In sum, all the factors we have identified — producer momentum toward expansion of production, low variable costs and large investments (often financed by consumers), large producer and consumer inventories, and a lack of new demand — imply that world uranium prices are likely to decline further (and probably significantly) over the decade.

For the next decade or two, this soft market will obviously be good for consumers. There will be many prospective sources of supply, allowing for diversification, stock building, and other measures to increase fuel security, and prices will be relatively low.

But in the longer run, will the buyers' market and low prices of the 1980s so dampen exploration and investment activity that uranium will not be available if more nuclear plants are later deployed? We think not. The historical evidence is that the uranium industry has been able to respond rapidly to upward shifts in demand, as the chart on page 21 shows for 1975 to 1979. Moreover, during periods of perceived market tightness, consumers have been willing to underwrite producers' risks in expanding production (for example, with interest-free loans for mines and mills), thus making possible large and early commitments to capacity. Indeed, one could argue that consumers, by their use of such mechanisms, are largely responsible for the looming excess capacity in the producing countries. We see little reason to expect fundamental change in this behavior.

What if there were a sudden return to the worldwide enthusiasm for nuclear power of the 1960s, with a new surge of reactor construction? No shortage of uranium could loom, at least until near the year 2000. The most important basis for this judgment is that the time required to order and build significant new reactor capacity is comparable to that required to develop uranium resources. What is more, the system has several ways to absorb the shock of any new wave of reactor orders. Inventories on both sides of the market will remain high; there will be considerable unused mining and milling capacity available whenever new demand arises; and production levels at many deposits are below what is economically and technically feasible. Direct consumer investment — such as occurred in previous periods of tight markets — will help accelerate industry expansion. Any country concerned about supply and fuel security should find a warm reception in most producer countries over the next decade and more.

Decreasing Nonproliferation Leverage

But while the energy-security concerns of consumers are alleviated by these market changes, other questions are raised. First, we must reconsider assumptions about desired directions of technological development. Many current programs for the development of nuclear power evolved in an era of pessimism about uranium supply and prices. While uranium supply is but one factor in decisions concerning the reprocessing of spent reactor fuel and the development of breeder reactors and laser enrichment of uranium, increased optimism about the cost and security of uranium supplies will surely change our perspective on (and probably delay our enthusiasm for) these new nuclear technologies. The prospect of ample, low-priced fuel for conventional

Uranium Supply

THE future supply of uranium depends on both the amount of uranium resources and the industry's success in discovering, developing, and producing these resources. Significant investment in discovery and development will be made by the private sector only with expectation of relatively near-term payoffs. As with other resources, exploration thus cannot be expected to yield proven reserves and resources in excess of any reasonable demand projected for 20 to 30 years.

Despite this, the ratio of known uranium reserves and resources to expected nuclear reactor requirements has grown rapidly over the past decade. According to data on uranium resources and demand compiled by the International Atomic Energy Agency (IAEA), reserves and resources outside the U.S. stood at about 1.4 million metric tons in 1967. Forecasters looking ahead the 10 or 12 years required to develop these resources estimated a 1980 nuclear capacity of about 240 gigawatts-electric (GWe), requiring about 38,000 metric tons of uranium annually. (Capacity outside the U.S. in 1980 actually reached only about 80 GWe.) Thus, estimated reserves and resources in 1967 were about 35 times as large as estimated requirements a decade thereafter. Or, put another way, the known resource horizon was perceived in 1967 to be 30 to 40 years off.

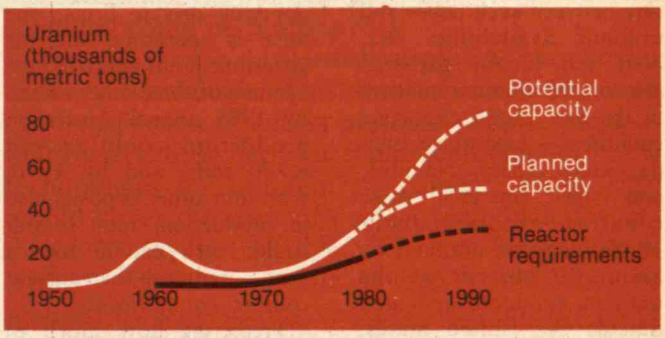
By late 1978, the IAEA's estimate of non-U.S. uranium reserves and resources had grown to 3.2 million metric tons, but non-U.S. nuclear capacity in 12 years (1990) was projected to be only 274 GWe. Thus, the ratio of reserves and resources to projected nuclear power needs grew to about 70 by 1978.

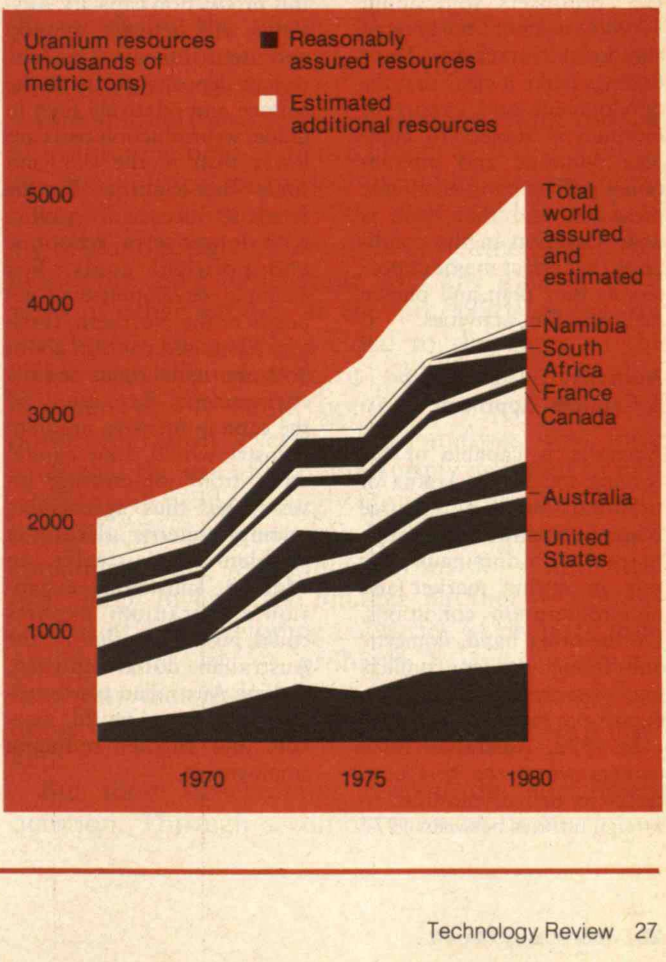
Perhaps even more reassuring for those concerned about supply security is the increased geographic diversification of uranium production. Overall, increases in reserves and resources in countries other than traditional producers (Canada, Australia, the United States, France, and South Africa) account for more than half the total increase over the past decade. Combined with new discoveries in traditional producer countries, many in new geologic environments and with ore grades higher than those already mined, these increases suggest that more exploration will reveal even greater uranium reserves and resources. The view that uranium is a mature resource, with exploitation proceeding to even lower-grade and more costly sources, is unjustified.

Resources and reserves of uranium ore do not automatically become fuel supplies, of course; substantial planning, investment, and development are required. The uranium industry was originally developed to supply material for weapons — a demand that dropped sharply in the early 1960s. These older facilities have now been supplemented by new investments, resulting in production capacities and output levels in excess of the uranium requirements of all commercial reactors. Only in the last few years has uranium demand approached supply: a mature commercial uranium market has only just begun to emerge. But it appears that the industry's investments are such that production capacity — and probably actual production — will significantly exceed demand. — *T.L.N. and H.D.J.* □

Top: Successful exploration and production programs have led to ever-increasing estimates of world uranium. This chart traces the course of estimates of world uranium resources by working groups of the International Atomic Energy Agency since 1967. The "others" category includes between 270 and 300 thousand metric tons contained in Swedish shales; that will be expensive and difficult to produce.

Bottom: The world uranium surplus. Planned production continues to exceed the needs of reactors in operation, under construction, and ordered, but is substantially lower than what could be produced with additional investment. The largest planned expansions of mining capacity are in Australia, Canada, and Niger, and these countries will be under the greatest pressure to restrain industry growth if new demand fails to materialize.





Uranium Exporters: Who They Are and How They Work

by Nancy Stauffer

NATIONS that depend on nuclear power have always been concerned about having reliable sources of uranium. Potential problems within exporting countries are a major source of this concern including: domestic conflicts over resource and environmental policy and social and economic issues that might significantly constrain future uranium production.

Recognizing the connection between such issues and uranium availability, Drs. Neff and Jacoby gathered data on the uranium industry in the five largest exporting countries — Australia, Canada, South Africa, Namibia, and Niger. (In 1980 those countries exported about 16,000 tons of uranium — about 80 percent of the uranium produced and used outside the United States. U.S. producers sold about 17,000 tons, but little entered the world market.) Their findings make it clear that the development and export of uranium is subject to complex domestic and international political and economic pressures, and that there is wide variation in the conditions that affect major exporters as they plan and pursue their uranium activities.

Australia: A Cautious Approach

Australia is capable of becoming the Saudi Arabia of uranium, with a resource base potentially large enough to give her a dominant position in setting market and nonproliferation conditions. On the other hand, domestic and foreign policy conflicts may severely limit Australia's export potential.

In 1972, Australian mine owners wrote the first contracts to deliver uranium to foreign utilities between 1977 and 1986. But a newly elected Labour government soon moved to replace private interests with public involvement in the uranium industry. Returned to power three years later, the Liberal Party — in American terms, the conservative party — began to loosen government control of the industry. Today, the government is selling its shares in the mines, foreign involvement is increasing, the industry is dominated by domestic private firms, one mine is operating, and the government has approved the opening of three other mines. By 1985 annual Australian production could exceed 6,700 tons, and by 1990, with four other deposits also in production, total output could reach 23,000 tons a year — far more than current contract commitments.

Predicting how much of this production capacity Australia will actually develop and use is difficult. The Australian deposits are near the surface and relatively high in grade, so production costs are lower than in the U.S. and some other countries. But the financial incentives conflict with longer-term economic and political goals. For example, development of deposits in the Northern Territory has raised concern about both aboriginal rights and the environment. Expansion of the capital-intensive uranium industry would draw capital away from job-creating investments, thus aggravating unemployment, already a problem in Australia. In addition, substantial expansion of uranium exports could push the value of the Australian dollar upward, making Australian goods less competitive on world markets and further reducing employment.

Canada: Internal Conflicts

Like Australia, Canada began exporting uranium for the American and British weapons programs, and an enormous industry developed: in 1959 Canadian uranium production reached 12,000 tons. Commercial contracting began in 1967, and Canada quickly became the world's largest uranium exporter. Today, the number of producers in Saskatchewan is rapidly increasing, and the traditional producers in Ontario are expanding their output.

According to Canadian law, the province of Saskatchewan owns its resources and thus can control resource development, participate in exploration and mining ventures, regulate occupational health and safety and environmental impacts, require employment of local native workers, and assess royalties. Most of Canada's new uranium development is taking place in Saskatchewan, and the province is exercising its powers.

Meanwhile, the federal government is empowered to set terms for and approve exports, control export prices, determine the level of foreign ownership — currently higher than desired — and dictate what portion of reserves is held for future domestic use. Conflicts between the federal government and the provinces over uranium policies continue and will probably intensify. The government is now trying to tax provincial resources, promising to return as much revenue as the provinces now receive. Meanwhile, the provinces have an increasing stake in federal export policies, since these policies may restrict their sales opportunities or conflict with regional political positions.

As the uranium market becomes more flexible, conflict may also arise over domestic pricing policies. Uranium deposits in Saskatchewan can be mined at a lower cost than those in Ontario, and the federal price-setting board may have trouble controlling low-cost producers in Saskatchewan. Ontario producers have relatively high-priced long-term contracts with domestic utilities, who would resent paying more than foreign buyers for fuel.

South Africa: Substantial Surpluses

The most striking feature of the uranium industry in South Africa is its secrecy: sales on the international market are not announced or even acknowledged, and disclosures concerning uranium are legally restricted.

Almost all South African uranium is extracted from material mined with gold as the primary product. The result is that uranium production is tied more strongly to the gold market than the uranium market. South Africa is likely to continue producing uranium even when demand is low, simply because the equipment is already in place, and recovering the uranium is certain to be cheaper now than later. Thus, the tie to gold mining also leads to uranium stockpiling.

South Africa's uranium production first peaked in 1959, seven years after the industry began, when 5,000 tons were extracted from two dozen gold-mining operations. Commercial exports began in 1972 and reached a record 5,200 tons in 1979. Until 1976, production substantially exceeded exports, so the present South African stockpile may be very large.

With more gold mines re-

covering uranium and new uranium-oriented ventures starting, South African production should expand in the next few years, rapidly exceeding contract commitments.

Namibia: An Uncertain Future

Namibia, under the territorial governance of South Africa since 1920, is relatively new as a major uranium producer. Its single source, the Rössing deposit, was first mined in 1975, produced 3,700 tons in 1979, and is expected to yield 5,000 tons in 1983, and production could expand further as a result of current exploration activities. South Africa has played a major role in developing Namibia's resources, and it continues to impose its rigid controls and secrecy on Namibian exports, including uranium.

The political evolution of Namibia will directly affect how much uranium is produced, how the output is distributed, and how quickly new uranium deposits are developed. The United Nations and many foreign governments endorse Namibian independence from South Africa, and if elections urged by the U.N. are held and result in a complete break with South Africa, operations at Rössing will probably be disrupted.

Already the debate over Namibian independence has affected uranium trade. The U.N. has called for sanctions against foreign governments that participate in Namibian affairs under South African domination. To avoid these difficulties, consumers have had to make curious and in some cases devious arrangements to maintain secure supplies, but Namibian uranium has remained available.

Niger: A Growing Market Power

Although Niger did not begin commercial production until 1971, her uranium exports are now becoming significant on the world market. Three new deposits found in the 1970s should begin producing by the mid-1980s; exploration is continuing in a dozen areas; and, based on past experience, more discoveries are likely. Considering only known deposits, Niger's output could increase from 3,350 tons in 1979 to 5,800 tons in 1983 and to 12,000 tons in 1986. Then, Niger could be producing more uranium than South Africa, becoming the fourth largest uranium supplier in the non-Communist world.

The government participates in all uranium exploration and development activities, owning 30 to 50 percent of every venture. But it also encourages participation by a diversity of foreign groups.

Uranium is already Niger's principal source of income, and the government's share of uranium revenues finances most national development. Because of the importance of these revenues, Niger is careful to maintain maximum flexibility in dealing with her development partners. For example, of the 10,500 tons of uranium that could be produced in 1985, Niger will retain the right to sell 3,900 tons, thereby retaining leverage useful in inducing old and new partners to make further investments.

Nancy Stauffer is editor of e-lab, *a quarterly report on research at the M.I.T. Energy Laboratory.* □

reactors will reduce the pressure for prompt availability of the breeder. This will make possible more extensive research and development, which may yield improvements in the economic, technological, nonproliferation, and other attributes of the liquid-metal fast-breeder.

Similarly, the reprocessing of spent fuel from conventional reactors to recover plutonium for use as reactor fuel could be deferred further if there is continued prospect for ample low-cost uranium. Under such conditions, additional uranium purchases and stockpiles will seem preferable to recycling in most nations. Thus, the political problems of a plutonium economy could be postponed.

There is now a substantial surplus of enrichment capacity worldwide. This surplus, combined with our expectation of excess uranium supply, suggests that there is little need for rapid deployment of new technologies for uranium enrichment, unless they would lower the costs of nuclear fuel. Such cost reductions may be possible with new laser or centrifuge technologies, but savings could also be realized by substituting cheaper uranium for more expensive enrichment services in existing facilities. (By increasing the amount of uranium used as feed for a given amount of fuel, the need for enrichment services can be reduced.)

Our findings also lead to questions about the use of uranium supply and enrichment services as leverage for political purposes, including nonproliferation policies. Until the 1970s, the United States held a world monopoly on uranium enrichment, and this monopoly gave us leverage over the nuclear decisions of other nations. In the late 1970s, when our enrichment monopoly yielded to the entry of the USSR into the market, it seemed possible that uranium supply could become the new focus of nonproliferation leverage. Our analysis now indicates that the use of uranium supply as a tool of persuasion will be increasingly limited at best and counterproductive at worst. As we have shown, major consumers have strong market positions, and most have large inventories. Smaller nations — notably several of the developing countries of primary nonproliferation risk — probably have even greater flexibility than industrial countries in meeting their needs for small amounts of uranium in today's market.

But these observations reopen the enrichment question. Through a combination of uranium and

The use of uranium supply as a tool of persuasion will be increasingly limited at best and counterproductive at worst.

enrichment supply, there may still be sources of political influence through the fuel cycle. For example, Japan and France (and now reportedly the United States) have engaged in discussions with Australia concerning construction of a facility to enrich that country's uranium. Vertical integration of this kind, with explicit consumer and producer involvement, could provide greater security by drawing key actors into a sphere of common interest. As supply security increases, nations are likely to be more willing to delay commitments that would spread proliferation-sensitive technologies. This new carrot approach may be better than the old stick.

U.S. Uranium Industry: Declining Viability

Changing world market conditions also raise serious questions about the ability of the U.S. uranium industry to preserve its long-run vitality. The industry faces growing costs owing to the advanced stage of exploitation of its resource base and high labor, regulatory, and other costs. Foreign ventures are often based on higher grade, larger, and more easily exploited deposits, and many fixed costs of these ventures have been underwritten by others. This threat of low-cost foreign competition may suffice to restrain domestic investments in exploration and development and thus threaten the long-term health of the American uranium industry.

This threat is extremely complex, involving not only domestic energy security but also nonproliferation, international relations, enrichment policy, and the potential for cartelization of the international market. Virtually all U.S. consumers depend on uranium enriched in the United States, as do many foreign buyers. There is clearly some sentiment for protectionist measures that would restrict use of these enrichment facilities by U.S. utilities to uranium of domestic origin, assuring U.S. uranium producers of a substantial domestic market. But to domestic and foreign producers, it might be preferable to keep world uranium prices close to long-run U.S. marginal costs. In this way all producers would be able to function within the same world market with no need for protectionist measures. But implementation of such "orderly marketing" arrangements would require formal or informal world price and production agreements (cartelization) and considerable government involvement.

There are two key issues — the potential for successful cartelization and the effects of such a cartel on nonproliferation and other international policy matters. While there is clearly a congruence of interest among producers — including the United States — it is questionable whether cartelization could proceed successfully. Economic tensions and political disparities among uranium producers are great — especially between the United States, Canada, and Australia on the one hand and the African producers on the other, particularly on the issue of whether strict nonproliferation conditions (such as restraints on reprocessing) should be attached to uranium sales. In at least some countries, internal friction among domestic firms, foreign participants, and local political interests would also work against national efforts to restrict market freedom. It is difficult to see how these differing interests could be reconciled in a cartel.

Finally, any effort to restrict sales in the interest of safeguards or other political goals would be seen by consumers as a threat to their fuel security and thus undermine nonproliferation efforts based on assured supplies of low-enriched uranium fuel. The United States, especially, is thus at the center of a host of conflicting interests involving nonproliferation strategy, enrichment policy, the viability of the domestic uranium industry, and its position in the world market.

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Thomas L. Neff is manager of the M.I.T. Energy Laboratory's International Energy Studies Program, and **Henry D. Jacoby** is professor of management and director of the laboratory's Center for Energy Policy Research. The authors acknowledge the assistance of Michael Lynch, Virginia Faust, Markus Rohrbasser, and Gordon Swartz in the research on which this article is based. Their research was supported by the U.S. Department of Energy through the M.I.T. Energy Laboratory, but the Department of Energy bears no responsibility for the results or views reported here. Preparation of this article was supported in part by the M.I.T. Center for Energy Policy Research.

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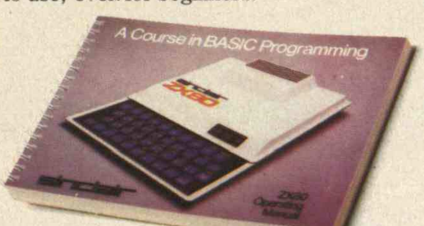

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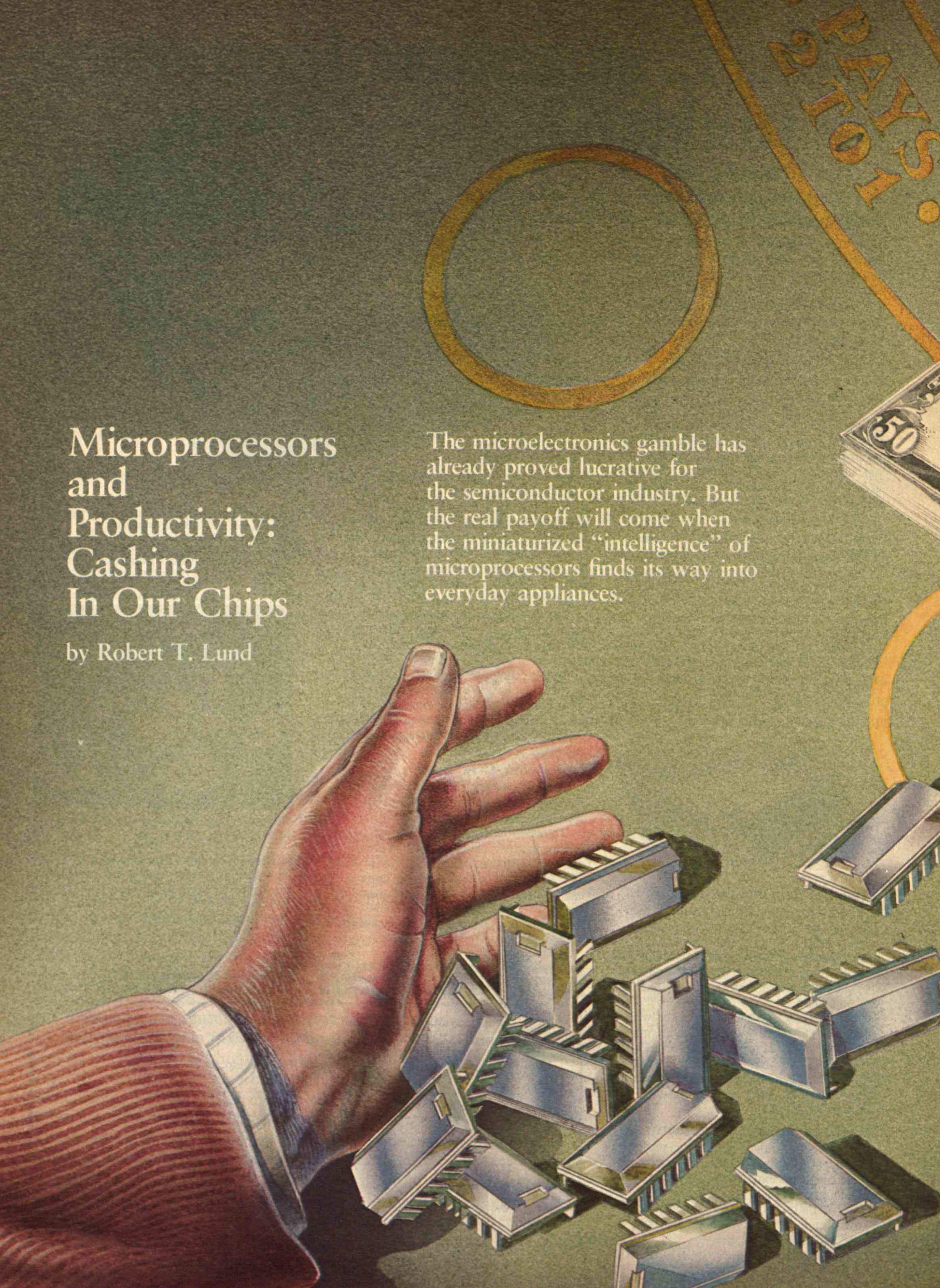
Microprocessors and Productivity: Cashing In Our Chips

The microelectronics gamble has already proved lucrative for the semiconductor industry. But the real payoff will come when the miniaturized "intelligence" of microprocessors finds its way into everyday appliances.

by Robert T. Lund



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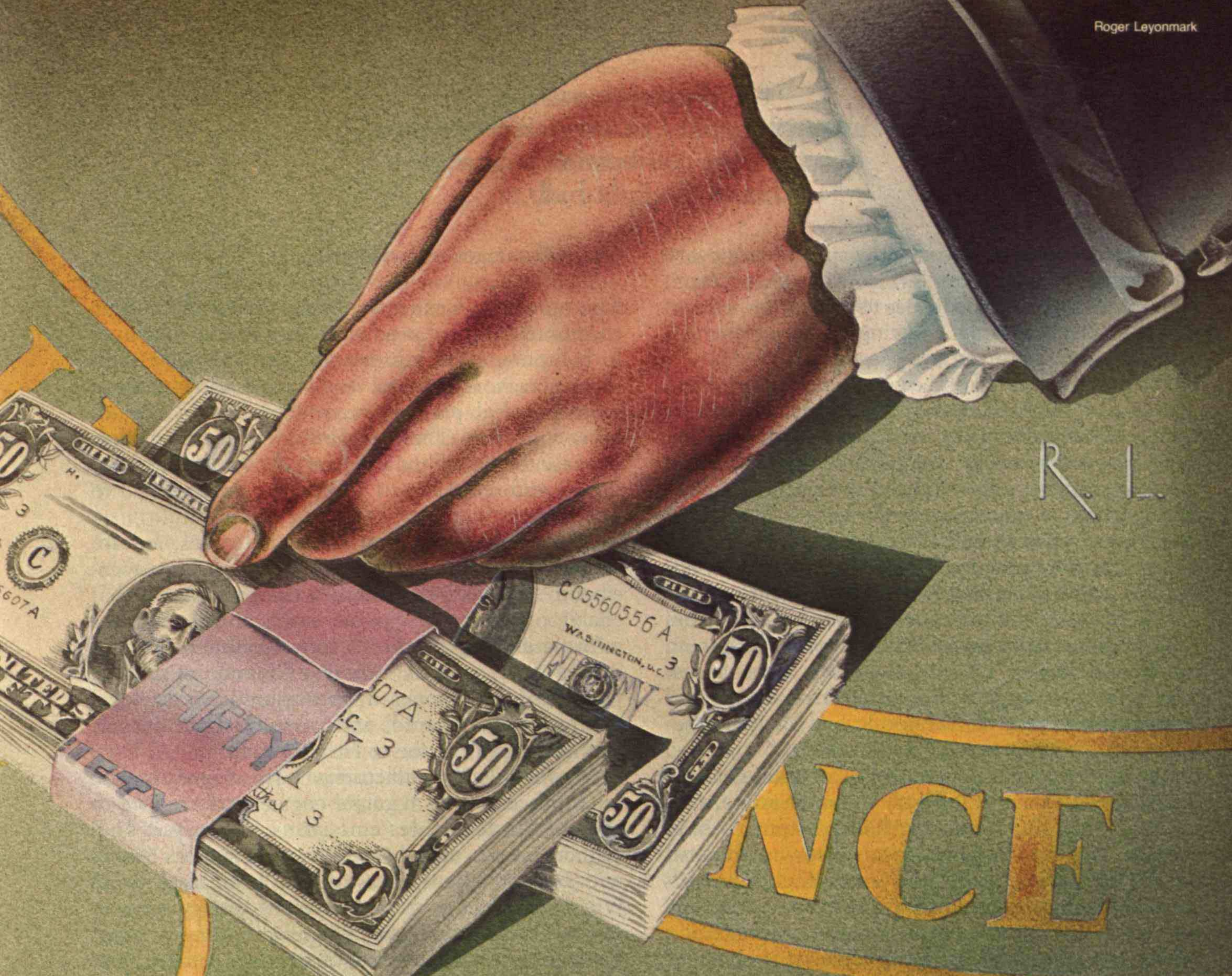


WHEN complete transistor circuits were first diffused onto silicon chips in the late 1950s, it became possible to add "intelligence" to products and processes. In practice, however, the high cost of custom designing chips for specific applications made them a practical addition only for mass-volume products such as watches and pocket calculators, or for applications where the value added was sufficient to justify the high cost.

Then in 1969, M.E. Hoff, an engineer for Intel Corp., began searching for an economical way to produce calculator chips and found he could incorporate the entire central processing unit of a computer onto a single silicon chip, thereby creating the world's first microprocessor. By attaching a few additional chips to supply other basic functions such as memory, he had, in effect, created a tiny programmable computer. This seemingly simple development launched a virtual revolution in machine intelligence.

Standard chips could be mass-produced and then tailored to specific uses by adding the appropriate programmed instructions, making "intelligence" available at low cost for virtually any application, however unique. And unlike other programmable devices — computers and minicomputers — microprocessors were not limited in their application by size, complexity, or power consumption.

In its own way, the microprocessor is as revolutionary as the wheel, the combustion engine, and the light bulb, because it has the potential to effect major changes in our quality of life. By 1978, microprocessors were being made by some 41 manufacturers offering more than 150 different models.

The microprocessor is as revolutionary an invention as the wheel, the combustion engine, and the light bulb.

Microprocessor applications now span almost every basic area of our lives — from transportation, manufacturing, and medicine, to recreation, education, and homemaking — bringing about changes for both manufacturers and users.

The potential social and economic implications of widespread microprocessor use, particularly with respect to employment, are viewed with growing apprehension in many countries. In Australia, microprocessors have been dubbed the "job killers." In Great Britain, a television show entitled "The Chips Are Down" portrayed the microelectronics era as a period of widespread job loss and economic upheaval, leading one member of Parliament to propose a ban on the import and use of microprocessors except under strict governmental control. Even in the United States, where people are more accustomed to mass applications of electronics, there is apprehension over the economic and social consequences of microprocessor applications.

The high level of concern in Great Britain led the British Department of Industry to fund a study, conducted by M.I.T.'s Center for Policy Alternatives, to examine the impacts of microprocessor use in existing applications in the United States. Eight products were selected for detailed study: heating, ventilation, and air-conditioning controls; automobile ignition sytems; word-processing devices; electronic postage scales; optical inspection systems in manufacturing; medical equipment; monitors for hydraulic cranes; and electronic sewing machines.

These products represent a range of applications in which microprocessors were used to enhance the performance of existing mechanical products. All were considered highly successful applications from a technical standpoint. Some were new products, radically different from anything previously available. Others were essentially an extension or enlargement of a firm's existing product line. In one or two cases, the microprocessor simply replaced many mechanical parts at reduced cost and with more reliable control. In other cases, the use of microprocessors resulted in a revolutionary change that opened new horizons for the product manufacturer.

The study examined each application from three points of view: What motivates the use of microprocessors? What is involved in generating a successful microprocessor-based product? And what are the impacts of microprocessor applications on producers, users, job skills, and employment?

The Advantages of Intelligence

Microprocessors can enhance the performance of an enormous range of products. They enable machines to compute, store information, communicate with their operators, control and time various events, sense physical parameters, and perform a host of other functions. These capabilities are combined to increase the flexibility, capacity, convenience, speed, safety, and reliability of an existing product and to lower operating costs.

In the field of written communications, for instance, microprocessors have transformed typewriters into highly sophisticated "word processors" that enable operators to type in, store, and manipulate information displayed on a screen before printing it out as final copy. A variety of functions such as pagination, centering, duplication, deletion, reorganization of material, and correction can be performed literally at the touch of a button.

Automobile manufacturers have begun to use microprocessors to regulate engine performance to reduce undesirable emissions, improve fuel economy, and control safety features such as brakes and airbags. Microprocessors are being used in all types of buildings to conserve the energy used in heating, ventilation, and air-conditioning systems through automatic control of start-up, setback, and peak-load limitations. And the incorporation of microprocessors into postage scales has greatly increased the accuracy and efficiency of postage calculation, saving thousands of dollars in postage and labor costs every year for firms that use them.

From the manufacturer's point of view, microprocessors offer considerable advantages as well. For instance, microprocessor-based logic circuits generally require far fewer chips than custom-designed circuits. For a simple application, a microprocessor may reduce the number of chips from fifty to two or three, thereby reducing the associated cost of packaging, circuit boards, power supplies, and space.

Microprocessors also replace the task of hardware design — the selection and interconnection of many components to produce custom-designed logic circuits — with software design, which involves writing, checking, and assembling computer programs. The resulting efficiencies make possible the relatively low cost of microprocessor applications.

Substitution of software design for hardware de-

Potential social and economic implications of microprocessors are viewed with growing apprehension in the industrial world.

sign also simplifies the job of engineering and designing new products. Laying out, testing, and debugging even moderately complex random-logic hardware can be very time consuming. By contrast, a software designer can shorten the time needed to program a microprocessor in various ways. Errors can be corrected by executing a simple program change rather than rewiring or redesigning a custom circuit. The efficiency of software design is enhanced by "development systems" that translate high-level programming languages such as Fortran into machine language for the microprocessor — a tedious and costly task if done by a human programmer.

Once the product has been manufactured, subsequent modifications and improvements can be made simply by altering the stored program — the production process scarcely needs to be touched. Products can be specially tailored for individual users through changes in the software. And once systems have been installed, software designers can make changes over telephone lines or mail new chips to product users at modest cost.

Microprocessor programs can also include testing and diagnostic routines that make it easier to use and repair the product and warn users about machine malfunctions. Microprocessor-based machines can monitor and regulate the accuracy of their own or operators' performance by comparing information about actual performance — obtained through measurement, calculation, or operator input — with fixed values stored in the memory. If discrepancies are detected, the machine can take corrective action, sound an alarm, or shut itself down.

Servicing is generally enhanced in microprocessor-based products. Simple repairs can be effected immediately — sometimes over the telephone — and operation restored without delay. Faulty modules can be readily removed and replaced. Certain products can even be programmed to lead the user step by step through simple diagnostic and repair procedures.

A Load Off One's Mind

Microprocessors enable a product to interact with its users in simple ways. This makes the product easier to use, shortens the time needed to learn how to use it, reduces operational errors, and makes the results more consistent. Users experience fewer failures because microprocessors can forestall obvious mistakes in control and operation. Thus, microprocessors can be used to enhance safety and operator performance. A particularly striking example of this among the microprocessor applications studied by the Center for Policy Alternatives is the Eaton Crane Load Computer.

Conventional hydraulic cranes require a high degree of operator skill. Safe tolerances in any given situation depend on the configuration of the crane itself and the load. Conventionally, a load chart for each crane is posted in the cab to help the operator work the crane safely, and instruments read out critical variables such as the angle on the boom and the tension on the lines. However, because of the complexity of crane operation, operators normally rely on experience and intuition to maintain safe performance.

Technical requirements vary enormously among cranes and loading situations, making the design of a suitable device exceedingly difficult through traditional approaches. In addition, the use of more than a simple monitor is still discretionary in the United States, which sets a modest limit on the price that an operator is willing to pay for such devices. These conditions make crane monitors an ideal application for microprocessors.

The Eaton Corp., a major U.S. capital equipment manufacturer, has developed a highly flexible microprocessor-based monitoring system that can easily be adapted to each machine and application through programming and data supplied by the operator. The same hardware can be used for all installations, with a single microprocessor programmed to compute the appropriate variables. Constants such as the load chart for a given crane are stored in the microprocessor's memory, and situation-specific parameters are introduced by the operator via a keyboard and display in response to a series of questions posed by the instrument itself. Using the input data, the microprocessor then computes safe operating parameters, such as boom accelerations and hook load, to great accuracy. In addition, the Eaton device allows the operator to set a variety of constraints on machine function — to avoid striking a wall or power line, for example — or to operate safely without actually seeing the load on the hook.

Because safety is critical, the Eaton system includes several features to ensure reliability of every

aspect of its operation. Values given by the operator are checked to make sure they are within a fixed permissible range, and self-calibration routines continually test the accuracy of the microprocessor calculations.

A major limitation of any such electronic instrument is the brutal treatment involved in crane transportation and use. Earlier electronic devices failed because the parts were shaken to pieces from vibration, shock, and pounding. However, the microprocessor-based monitoring instrument console is compact enough to be removed for separate transport.

The Eaton system was developed when the firm's technical management, recognizing a need to attain competence in using microprocessors and electronics, chose the Crane Load Computer as a means of strengthening their existing product line. Visits to crane manufacturers made it apparent that an "intelligent" and refined product was required. One engineer was assigned full time to the project, and he carried out the development and testing of the device with the part time help of one mechanical designer and one programmer-engineer. The design work was essentially completed in 18 months.

The electronic monitoring system was developed over a three-year period through intimate contact with a major crane manufacturer, and it has been tested in several installations. Initially, experienced crane operators were skeptical of the apparent complexity of the keyboard input and instrument display, but the value of the instrument to their own safety and effective operation became apparent once they used the machine. Modifications are continually made in response to users' suggestions through changes in the software rather than the hardware design.

The success of a commercial version of the Eaton device has yet to be determined. It is likely to be cost-competitive with other complex monitoring devices, but because the Eaton system has remarkably superior performance, its market potential may be high compared with other products currently available.

A Stitch in Time

The Athena 2000 — Singer's revolutionary electronic sewing machine — is another excellent example of the application of microprocessor technology. Introduced in 1975 after four years of secret design and development, the Athena 2000 is a highly flexible instrument, programmed to perform 25 different stitches at the twist of a dial and the press of a button. The change from an electromechanical machine to an electronically controlled machine has simplified the operator's task while retaining the sophistication of the most advanced mechanical models.

To develop the Athena 2000, the project manager and a core group of about eight engineers stayed with the project from inception to first production, working in secrecy. Electronic parts were purchased through another Singer division to disguise the fact that the sewing-machine division was interested in electronic components.

Formal work on the machine began in mid-1971. A major bottleneck in the development effort was in marrying electronic controls to mechanical parts. In conventional machines, the mechanical assemblies are driven by an electric motor with sufficient power to overcome minor friction from such common occurrences as tight fits and burrs on parts. When these mechanical linkages were driven by linear servos that were in turn driven by power transistors, excessive friction in the system caused the transistors to overheat and burn out. This difficulty carried over into production start-up, where more precise standards had to be imposed on mechanical parts.

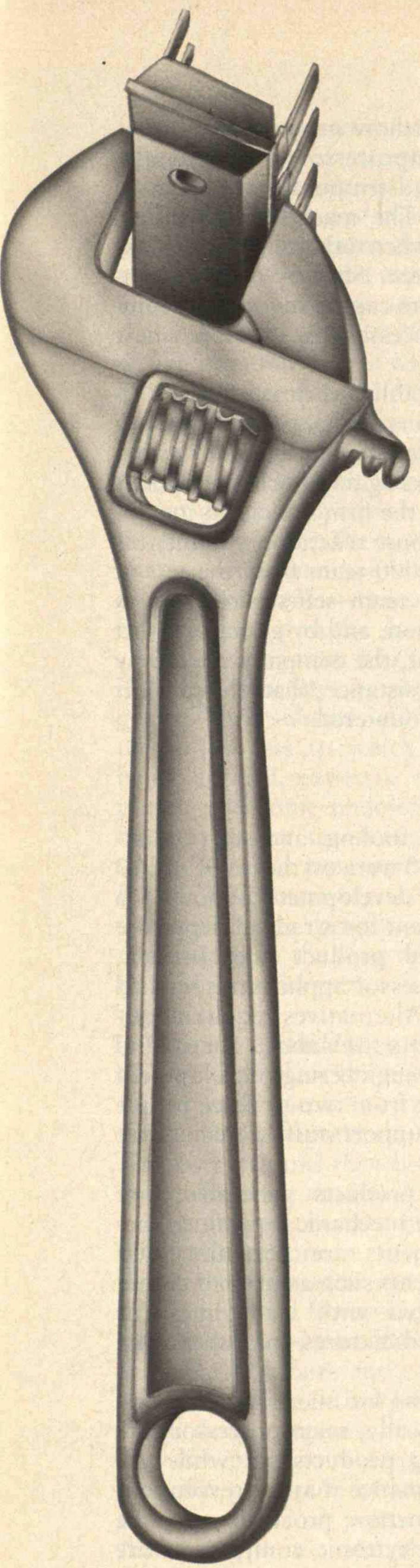
The Athena 2000 was introduced as Singer's top-of-the-line machine at a price of $900, well over that of a comparable mechanical sewing machine. It was an immediate success despite the fact that it was introduced during a time of slumping sales in household appliances. Singer has introduced several other electronic sewing-machine models since the Athena, capturing an estimated 5 to 6 percent of the 1.8-to-2.0-million-units-per-year domestic sewing-machine market. Although the unit volume does not constitute an appreciable fraction of the market, the significantly higher prices of the electronic machines make the dollar share quite respectable.

The revolutionary design change apparently caught Singer's competitors by surprise. No comparable machine has yet been introduced by a competitor, and Singer has been able to enjoy at least a five-year advantage to recover its initial investment and bring its manufacturing costs down in preparation for competition.

The electronic sewing machine has had notable

Microprocessors and Labor: Whose Bargaining Chips?

by Harley Shaiken



Paul S. Weiner

POTENT new forms of automation based on silicon chips, such as robots and word processors, are pervading a wide variety of workplaces. Because the new technology could displace workers, particularly in times of sluggish economic growth, and change the nature of jobs that remain, it raises some critical questions. How will the speed and shape of technological development be determined, and what might be the social costs?

Although employment depends on more than technology, microelectronics affects jobs in numerous ways. Unlike previous forms of labor-saving technology, microelectronics extends to every sector of the economy. Office automation, for example, reduces the number of white-collar opportunities once available to blue-collar workers. A 1978 report to the president of France projected that by 1990, 30 percent fewer workers may be needed to produce a given volume of work in the insurance and banking industries.

Moreover, microelectronics changes the product as well as the production process. Not only can electronic cash registers be partially put together by robots, but they contain far fewer parts to manufacture and assemble. This may limit the potential of companies that manufacture microelectronics-based products to create jobs. The European Trade Union Institute cites a study by Olivetti Corp. of eight such international firms with an average employment decrease of 20 percent between 1969 and 1978.

It is often argued that unless we implement the latest in automation, even more jobs will be lost to the competition that does implement. But this argument fails to address the substantial job losses that could occur for firms that effectively compete by automating. And even if enough jobs become available in the overall economy, the transition to the new technology is important. Will displaced workers be able to relocate to better jobs, or will they be relegated to less desirable jobs — or no jobs at all? To the extent that individuals are able to relocate, what happens to communities centered around industries with plummeting employment?

Microelectronics can create new skills and decentralize decision making. But it also lays the basis for rendering skills useless and increasing the control over workers. A report by the Machine Tool Task Force, a project funded by the U.S. Air Force, recommends that industry "*reduce the skill levels* required to operate or maintain certain machine tools (or to plan the manufacture of a part), an approach already practiced by some of the technically more advanced companies. This can be done by using more automation and substituting computers for people in executing certain decisions or operations."

These trends are triggering apprehension and debate in labor unions throughout the world. Some innovative and unprecedented responses have resulted. In Britain, the Trade Union Congress has demanded that "no new technology be introduced unilaterally by management." While most British unions argue that new technologies should not displace currently employed workers, some groups have also demanded that the microprocessor not reduce the number of future job positions. Productivity gains, they reason, should translate into a shorter work week at the same pay rather than into fewer jobs. And workers at Lucas Aerospace have proposed the manufacture of new, socially useful products such as heat pumps as an alternative to job loss.

In its 1979 contract negotiations, the United Auto Workers (UAW) union presented proposals to both General Motors and Ford concerning microprocessor-based technology. The Ford proposal sought to involve the union at "the level of design and implementation" of new technology to prevent the devaluing of skills and increasing of control over workers. To ensure that its guidelines would be met, the union demanded the right to strike over technology-related issues.

Union leaders at UAW Local 600, which represents over 30,000 workers at the Ford Rouge plant in Dearborn, Mich., have sought to make technology an issue on the shop floor through classes, forums, and newspaper articles so workers themselves can begin formulating alternative proposals.

In the past, unions were primarily concerned with wages and job security. Although these issues remain central, new approaches stress active participation of unions in decisions shaping the design, deployment, and use of technology. In fact, bargaining over technology may become a prominent feature of labor-management relations in the coming decade.

Harley Shaiken is a labor and technology analyst, and a research fellow in the Science, Technology, and Society Program at M.I.T.

A secret incubation period protected the Athena 2000 from reactionary forces within Singer's establishment.

impact on various aspects of Singer's operations and its competitors. The advent of the Athena 2000 entailed changes in manufacturing processes, locations, work force, and management. The switch from electromechanics to electronics enabled Singer's engineers to remove approximately 350 mechanical parts from the 700 moving and nonmoving parts in a conventional machine. This resulted in significant changes in the manufacturing process: overall workspace requirements, capital equipment costs, settings and adjustments required during assembly, and overall production time were reduced. These changes shortened manufacturing start-up time and improved product quality. Similar changes in parts and assembly processes reduced manufacturing time and work-in-process inventory, but the higher value of raw materials and purchased parts tends to cancel any reductions in capital. Furthermore, because components are more specialized, the number of suppliers is reduced, so that Singer is now more dependent on its suppliers and consequently is vulnerable to delays and price increases. Also, the levels of worker skill needed to make the electronic machine are clearly lower than those required for electromechanical models, with more people in light assembly and fewer in machine operations and setup.

In supervision and management of manufacturing, on the other hand, the required skill levels have risen, particularly for analytical skills to diagnose intangible problems. Buyers for the firm also needed to become more sophisticated because parts once made by the firm have been replaced by electronic components purchased from outside. Field personnel needed to be retrained to handle the new machines. Training aids now consist of tabletop simulators displaying machine functions and interconnections. Servicing requirements have been reduced because the Athena is more reliable than its mechanical precursors. Service personnel are given diagnostic aids only, and field repair of electronic components is restricted to removing and replacing printed circuit boards. Faulty modules are returned to the factory.

Altogether, introduction of the Athena has apparently reduced total employment. However, the reduction is probably much less than would have occurred if the Athena had not been introduced. Singer has kept manufacture of the top-of-the-line sewing machine in the United States, thus preserving many domestic jobs that would have been lost to competing foreign imports or offshore manufacture.

The success of the microprocessor-controlled sewing machine had at least a temporary rejuvenating effect on the company. The machine contributed substantially to profits when other lines were experiencing a profit squeeze. Start-up was accomplished with only moderate capital investment compared with the capital necessary to develop a new mechanical machine.

It is unusual for an established firm with a 100-year tradition of evolutionary change to develop a product so radically different; the climate within such a firm normally works against such attempts. A key factor in success was the firm's decision to protect innovation from in-house reactionary influences by isolating the Athena 2000 team from the rest of the firm. By making the team self-sufficient from inception to implementation, and by giving it direct access to top management, the company effectively bypassed the internal resistance that the project normally would have encountered.

Winning Strategies

Total development costs, tooling, and start-up expenses for the Athena 2000 were on the order of $10 million for the four-year development period — a relatively modest investment for a radical departure from a firm's traditional product line. In fact, virtually all the microprocessor applications studied by the Center for Policy Alternatives required relatively modest investments of labor, time, and money. In every case, engineering development teams were small, ranging from two or three people to no more than twenty. Support staffs were likewise of moderate size.

Microprocessor-based products generally took less time to develop than mechanical products because electronic components are normally shelf items. Tooling time for items such as printed circuit boards is short compared with lead times for machines, tools, dies, and fixtures for fabricating mechanical parts.

The financial investments for microprocessor applications were low. Typically, microprocessors are being applied to existing products, so while the change in product performance may be revolutionary, the effect on production processes may be minor. Where standard electronic components are used, only assembly and testing processes may be af-

As firms develop the skill to apply microprocessors to their products, they will pursue other opportunities, spurring innovation.

fected. Little is needed in the way of new assembly equipment, and electronic test equipment tends to cost less than traditional production machinery.

Certain design and manufacturing strategies appear to be important for successful product development. Where the microprocessor application is a radical innovation to an existing product line, as in the case of the Athena 2000, the project needs the strong commitment of top management and isolation from the rest of the firm during the incubation period. This is as much to protect the new idea from negative thinking within the firm as to avoid premature leaks to competitors. Where the application is not in direct competition with existing products of the firm, or where the application is an evolutionary change — for example, microprocessor controls in microwave ovens — this principle may still be useful but less crucial to the success of the project.

The development team for each product studied included two key people. One, the "design integrator," had substantial knowledge about the product or process to which the microprocessor was being applied, expertise in several technical disciplines, and some understanding of electronics and microprocessor technology. The other key person was a "creative programmer," who was responsible for the efficiency, versatility, and reliability of the microprocessor programs. Careful programming contributes to the long-term success of the product by adding to its performance capabilities or reducing its cost.

One successful design strategy in several applications was to place the sophistication of the product in the microprocessor memory rather than the mechanical components. Changes in tables, parameters, or programs then become the mode for rapid, low-cost future modifications.

The greatest design difficulty in microprocessor applications appears to involve the interfaces between the microprocessor and the mechanical parts of the product. Designing sensors and actuators — the components that inform the microprocessor of the state of affairs and carry out the microprocessor's commands — is a particularly demanding task. Good design depends on an intimate knowledge of how the product must perform. This may explain why many of the firms we studied preferred to train existing technical personnel in electronics rather than bring in microprocessor experts and acquaint them with the product and users' needs.

A general marketing strategy has been to introduce the microprocessor-controlled product as a top-of-the-line item. This is a logical approach where microprocessors enhance product performance and provide greater value to the user. The greater profit margins normally found in the higher-priced items help to repay development costs, while prices tend to limit demand as the firm is building production capacity and correcting deficiencies. In the long run, however, many microprocessor applications will result in less costly products and price reductions when competition develops.

Although evidence is quite limited, it appears that the application of microprocessors in one product line may be a company's first step into a series of new market areas. Once a firm sees that the functions performed by microprocessors in one application can be readily transferred to products for other markets, it may be able to diversify its product line, a decided stimulus to innovation.

Microprocessors and Jobs

Microprocessors can have dramatic effects on workers' job content, location, and employment levels in all aspects of product manufacture and use — from production workers, supervisors, and engineers to inspectors, maintenance technicians, salespeople, and service personnel.

Manufacturing operations are likely to undergo substantial change, with expanded requirements for light electronic assembly, reductions in the production of mechanical parts, and a shift from final mechanical inspection to in-process electronic testing of components and assemblies. This entails changes in job skills as well. For example, production and service jobs tend to be deskilled when metal-working jobs are replaced by simpler light electronic assembly. Engineers' and supervisors' jobs, on the other hand, tend to become more demanding. As devices become more sophisticated, training and retraining requirements will increase.

The employment effects of microprocessor applications tend to be hidden. A shift in job contents within a single firm may actually cause simultaneous layoffs and new hirings. The labor used per unit of output may decrease, but market expansion obscures this fact by requiring greater employment on the whole. And the loss in market share by a

Continued on page 44

The International Stakes in Microelectronics

by Colin Norman

WITH sales amounting to well over $100 billion a year and manufacturing plants spread around the world, the electronics industry is now among the leading sectors of the global economy. Within a decade it is expected to rival automobile production as the world's largest manufacturing industry, and by 1990, the market for electronic goods may reach about $400 billion a year.

The electronics industry will critically affect many other industries by changing production processes, speeding up the handling of information, spawning markets for new consumer goods, and improving productivity. Indeed, it appears likely that the advanced industrial societies will need to reorganize their production systems around the electronics complex.

Chipping Away at American Dominance

Technological innovation has always played a key role in the world economy. Post-World War II advances in petrochemical and synthetic materials technologies, for example, deeply affected markets for natural products and stimulated new areas of growth in the industrial countries. But developments in electronics are likely to affect such a broad range of activities that their economic impacts will be unprecedented.

In response, the industrial nations have begun to examine the health of their electronics industries, focusing on relative international standings in the critical race to develop and market ever more powerful integrated circuits. Furthermore, they are devising ways to encourage other sectors of their economies to adopt the new technologies.

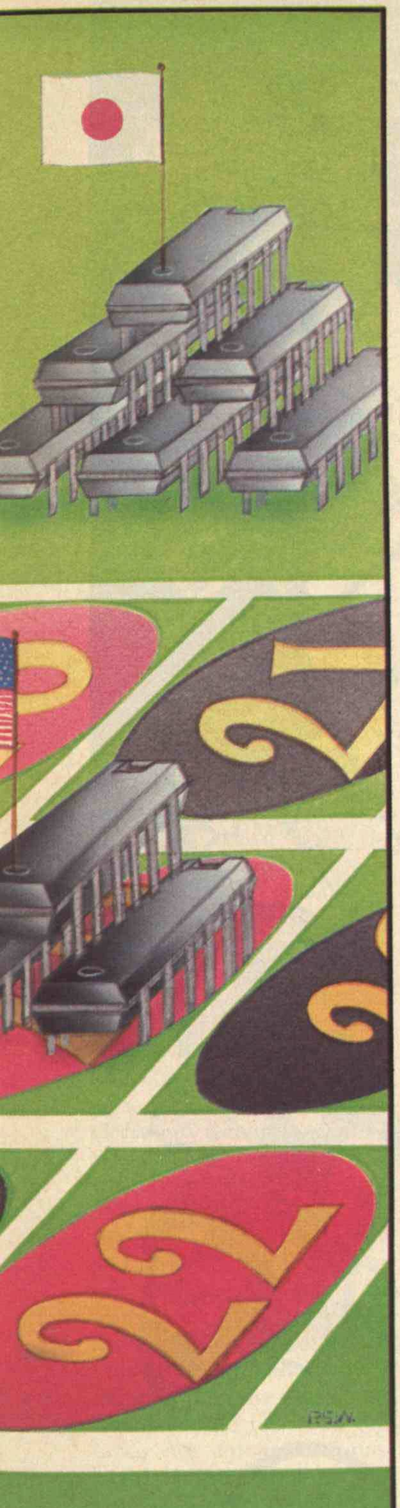
The United States has long dominated the development and marketing of microelectronics. Virtually all the early innovations were made in the United States, and American companies account for more than 70 percent of the world's production of integrated circuits. But the structure of the U.S. semiconductor industry is changing, and rapid technological advances by Japanese companies are beginning to threaten American technological hegemony in some areas.

The key innovations have mostly been made by a handful of U.S. companies established in the 1960s with a few million dollars of venture capital apiece. Some of these companies have since joined the ranks of major American corporations.

These small innovative companies eclipsed the big electronics conglomerates such as RCA and Westinghouse by moving rapidly into commercial production of each new technological breakthrough. The bulk of the integrated circuits produced in the U.S. are still made by companies that primarily manufacture microelectronic components and sell them to manufacturers of electronic equipment. In addition, IBM, American Telephone and Telegraph, and General Motors manufacture integrated circuits for their own use. A very different structure prevails in Japan and Europe, where the production of integrated circuits is dominated by giants such as Hitachi, Nippon Electric, Siemens, and Philips.

In the past few years, however, several American semiconductor companies have been taken over by large corporations, a development that some fear will cause these companies to lose the flexibility to make rapid investment decisions. More-

Paul S. Weiner



over, about 15 percent of the American semiconductor industry has been bought up by foreign firms in the past few years. Fairchild Camera and Instrument Co., for example, was acquired in 1979 by the French-American oil conglomerate Schlumberger, and the Dutch electronics company Philips has taken control of Signetics. At the same time, some of the leading Japanese semiconductor manufacturers have established manufacturing facilities in the U.S. The industrial environment surrounding the production of integrated circuits in the U.S. is therefore changing fast.

One reason is the escalating cost of establishing new production facilities. The cost of setting up a new production line to make the most advanced circuits is about $40 million, a far cry from earlier days, when whole new companies could be established for one-tenth that amount. This thirst for cash is one reason why so many of the original smaller companies have been willing to accept offers from large corporations.

Over the years, American semiconductor manufacturers have received substantial financial support from the federal government. The Department of Defense and NASA funded some of the early research and guaranteed a market for the first integrated circuits.

A new $200-million Pentagon-sponsored project to develop "very high speed integrated circuits" (VHSICs), which will perform electronic functions at extremely high speeds for use in military hardware, is likely to produce techniques with commercial applications and could help preserve the technological edge of the United States. However, several semiconductor manufacturers are wary of getting involved with the program because they fear that it will divert their efforts from commercially oriented technologies. Moreover, they suggest, the VHSIC program does little to offset the support that their Japanese rivals receive from their government.

Rise and Fall

The Japanese recognized in the early 1970s that electronics would be a cornerstone of industrial progress in the coming decades, and the government launched a program to foster a domestic microelectronics industry. Trade barriers were erected to fend off foreign competition, and a joint government-industry program was initiated to develop large-scale integrated circuit technologies. The government put about $250 million into the program, about 40 percent of the total. In addition, because they are part of the large industrial conglomerates, Japanese microelectronics companies have little difficulty raising the capital necessary for large-scale production — an advantage enhanced by liberal banking rules.

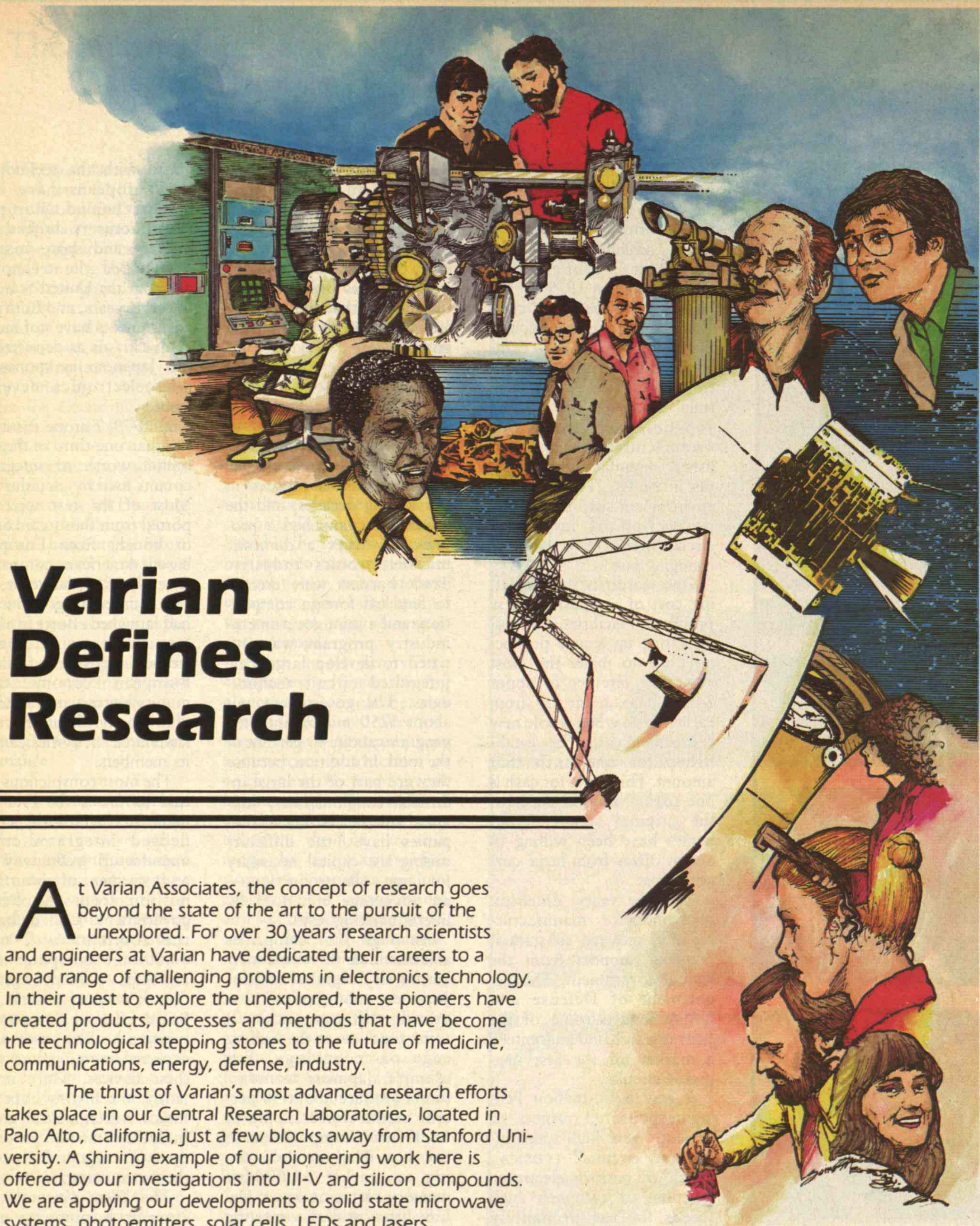
Although U.S. companies still dominate the world market for all integrated circuits, Japanese companies now provide stiff competition in some products at the leading edge of technology. For example, Japanese manufacturers produce about 40 percent of the world supply of 16,000-bit computer-memory chips. They are also starting to market 64,000-bit memory chips, as are a few U.S. firms, and at a meeting early in 1980, Japanese engineers stunned their American colleagues by unveiling designs for chips containing 256,000 memory cells.

While American and Japanese firms have been racing ahead with the technology, the Europeans have been lagging behind. European manufacturers lacked the military and space markets that pulled the technology along in the United States in the early years, and European governments have not moved as quickly or as decisively as the Japanese in sponsoring microelectronics development.

In 1979, Europe produced less than one-third of the $1.6 billion worth of integrated circuits used by its industries. Most of the rest were imported from the United States or bought from European-based American companies. By early 1980, however, several European governments had launched efforts to stimulate domestic microelectronics industries, and the European Economic Community has initiated a modest effort to coordinate electronics-related activities among its members.

The most conspicuous venture so far is the establishment in Britain of a full-fledged integrated-circuit manufacturing company with an investment of about $120 million from the British government. Called Inmos, the company will make 64,000-bit computer-memory chips — the next generation of memory circuits. The British effort is aimed at capturing a healthy share of the expected booming market for these devices. More importantly, the British hope that Inmos will stimulate greater interest among potential users of integrated circuits in their own country.

The West German government is pumping about $25 million per year into research-and-development efforts designed to produce state-of-the-art integrated circuits. And the French government is using its muscle in the marketplace to stimulate



the development of domestic semiconductor companies. To meet military and telecommunications needs, French government agencies buy about half the integrated circuits used in France and give priority to French firms and joint French-American ventures in their contract awards.

Even more important than the race to produce and market integrated circuits is the race to incorporate these devices into products and processes; this secondary economic impact will be enormous. The United States is currently the world's largest user of microelectronics-based devices, although Japan is steadily increasing its share of world consumption.

U.S. dominance arises partly from the fact that American computer firms — the largest users of microelectronics — hold a commanding position in the world market. IBM alone accounts for more than half the worldwide sales of computers. But in other areas such as consumer electronics, industrial control equipment, and office machinery, U.S. companies have moved rapidly to incorporate microelectronics into their products.

In Japan, there is a concerted effort to move microelectronic technology into a variety of industries as quickly as possible. Japan already boasts at least half the world's working robots, and a vigorous program supported by the Ministry of International Trade and Industry is racing to develop new industrial automation techniques. Japanese steel, automobile, and television factories are among the most highly automated in the world, and the resulting efficiencies have helped them capture a large share of the world market for these goods.

European governments are also sponsoring ambitious programs to encourage domestic industries to adopt new microelectronic technologies. In Britain, for example, the government has established a company to design and manufacture electronic office equipment, and it is investing about $100 million in a program designed to boost awareness of microelectronics and assist British industry in using the technology. France, Italy, and West Germany have launched similar efforts. All told, European governments are spending about $1 billion to stimulate domestic production and use of microelectronics, and private industry is investing about the same.

It is worth noting, however, that in the United States, IBM alone invests more than $1 billion each year in research and development. The Europeans clearly face some difficulties in overtaking the long lead of the United States and closing the gap between themselves and Japan in the development and application of microelectronics.

Third-World Woes

European, Japanese, and American economic policies are all directed at the same goal: to protect domestic industries against the threat of foreign competition in manufactured goods by stimulating innovation in new products and processes. Clearly, these moves have important implications for developing countries, which are also hoping to expand their share of markets for manufactured goods. Yet the impact of the microelectronic revolution on the Third World has so far received scant attention.

Microelectronics technology is likely to affect the prospects for developing countries in two ways. First, the automation of factories in the industrial countries through microprocessor-controlled machinery and computerized assembly may erode the comparative advantage that developing countries, with their lower labor costs, now hold. And second, if the electronics industry does become a stimulus for growth across a broad spectrum of other industries, its concentration in the industrial nations is likely to widen the gap between rich and poor countries.

While these impacts will differ greatly from industry to industry, two industries from which developing countries have derived much of their export earnings — textiles and electronics — could be deeply affected by the new technologies.

The manufacture of garments has always been a labor-intensive business in which developing countries have enjoyed a comparative advantage. But new technologies are cutting into labor requirements in industrial nations. A computerized system for laying out patterns on material, combined with electronically controlled laser cutting, has reduced the number of skilled workers in one British plant from 200 to 20. And microprocessor-controlled sewing machines may similarly affect the task of sewing clothes. Although fully automated garment production is still a long way off, these changes are laying the foundation for a much less labor-intensive process.

Electronic goods, the third largest category of manufactured exports from the developing countries, are virtually all under the control of multinational corporations, which ship electronic components to the developing world and reimport finished products. Such "offshore" assembly extends from the delicate process of attaching fine wires to integrated circuits, to the final assembly of electronic goods.

But even the creation of jobs through this arrangement may slow down under the impact of new automation technologies. The testing and soldering of integrated circuits is now being automated, for example. In the manufacture of electronic goods, the reduction in labor requirements by Japanese television companies — a 50 percent drop during a period when output rose by 25 percent — points to future trends. Such computerized assembly may become a major determinant of international competition in this industry, and there is likely to be less incentive to locate assembly plants in developing countries.

It is important to keep the impact of microelectronics in perspective, however. The structure of the global economy will be more immediately and deeply affected by such developments as rising energy prices, changing demand for consumer products, protectionist import policies, and global inflation. But by constituting a new pole of potential growth and changing the labor content of various production processes, microelectronics is going to play an important, if more subtle, role in shaping international economic relationships in the decades ahead.

Colin Norman is a science writer and researcher for the Worldwatch Institute in Washington, D.C. This article is adapted from his recently published Worldwatch study, Microelectronics at Work. □

Those who fail to adopt the new technologies will not be able to compete in the microprocessor-based economy.

competitor may result in layoffs elsewhere. This combination makes it difficult to determine which effects are specifically attributable to the advent of a product using a microprocessor.

In the short term, the firms we studied tended to experience higher employment, probably because of increases in market share or general market expansion. The longer-term effects are less clear. As a firm goes from rapid changes in product line to a period of consolidation and standardization, increases in output may well be possible with no further increases in employment. Furthermore, as competing firms develop similar products, the employment increases of early entrants may prove temporary.

In our study, employment in the firms *using* microprocessor-based products was either unchanged or reduced. Half of these firms reported greater worker productivity but no reduction in employment levels, at least in the short term. A few user firms experienced productivity increases of one-third or more and some reductions in employment. In several instances, operators' work shifted to maintenance and monitoring tasks — keeping the device running smoothly and checking its output.

It seems likely that the more important employment effects will involve firms that retain conventional technology. These firms may experience a reduction in employment or a curtailment in growth as their competitors' microprocessor-based products capture larger shares of the market. More seriously affected may be those firms making parts such as conventional control systems or timing switches that perform functions that can be handled more elegantly with microelectronics.

It also seems likely, based on our examination, that the demand for software for microprocessor applications will create a substantial number of programming jobs. A billion dollars worth of programming material has already been created for one microprocessor, the Intel 8080. It is quite possible that the total value of application-and-development systems and software sold by suppliers and service firms will ultimately exceed the value of the microprocessor chips themselves.

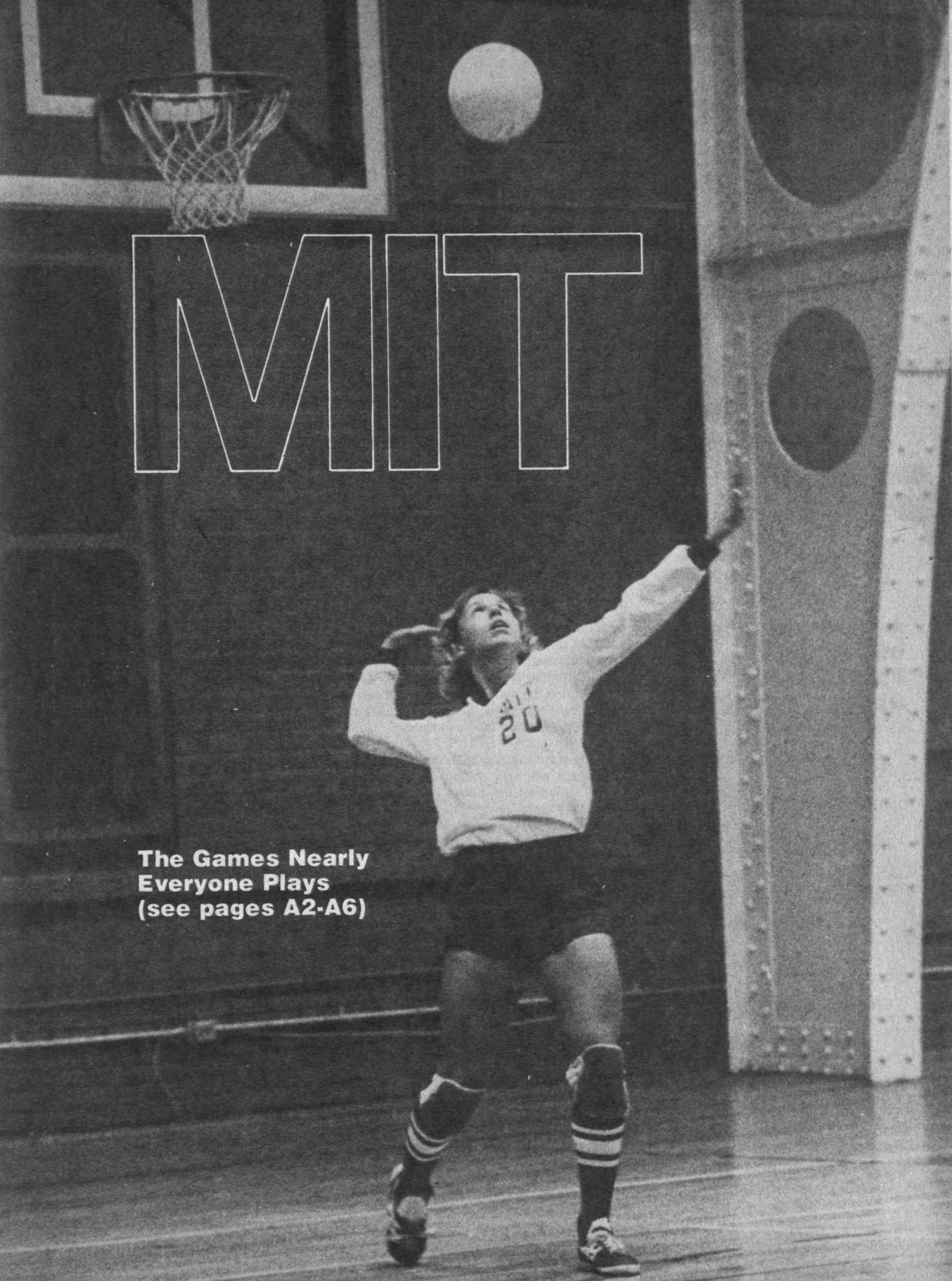
Straightforward microprocessor applications are occurring rapidly today. Entry costs are low, capital requirements are modest, and products can be designed relatively rapidly and inexpensively. Firms entering this market have available more standardized parts and more powerful tools than earlier firms. These factors may explain why it has been easy for small new firms to break successfully into existing markets with innovative products. How long this strategic window will be open remains to be seen. As more advanced microelectronics become available, as the emphasis on software and tailoring products to customers' needs increases, and as simpler applications are completed, a firm will need more sophisticated system designs, software, and production capabilities to compete successfully. Entry costs will surge. Firms entering late could be at a serious disadvantage compared with companies that have already begun to develop skills and understanding of this new technology.

Competition has traditionally been limited by the need for large investments in equipment for making parts, by the availability of highly skilled labor, and by long, expensive product-development periods. What will happen now that products can be more easily and efficiently assembled with different combinations of standard modules? Some manufacturers have speculated that product life may be markedly shortened by the advent of microprocessors, thus requiring more rapid payback of development and tooling costs. Indeed, some firms have tried to protect their positions by building more flexibility — extra keys or buttons, for example — into their products and systems than is immediately needed.

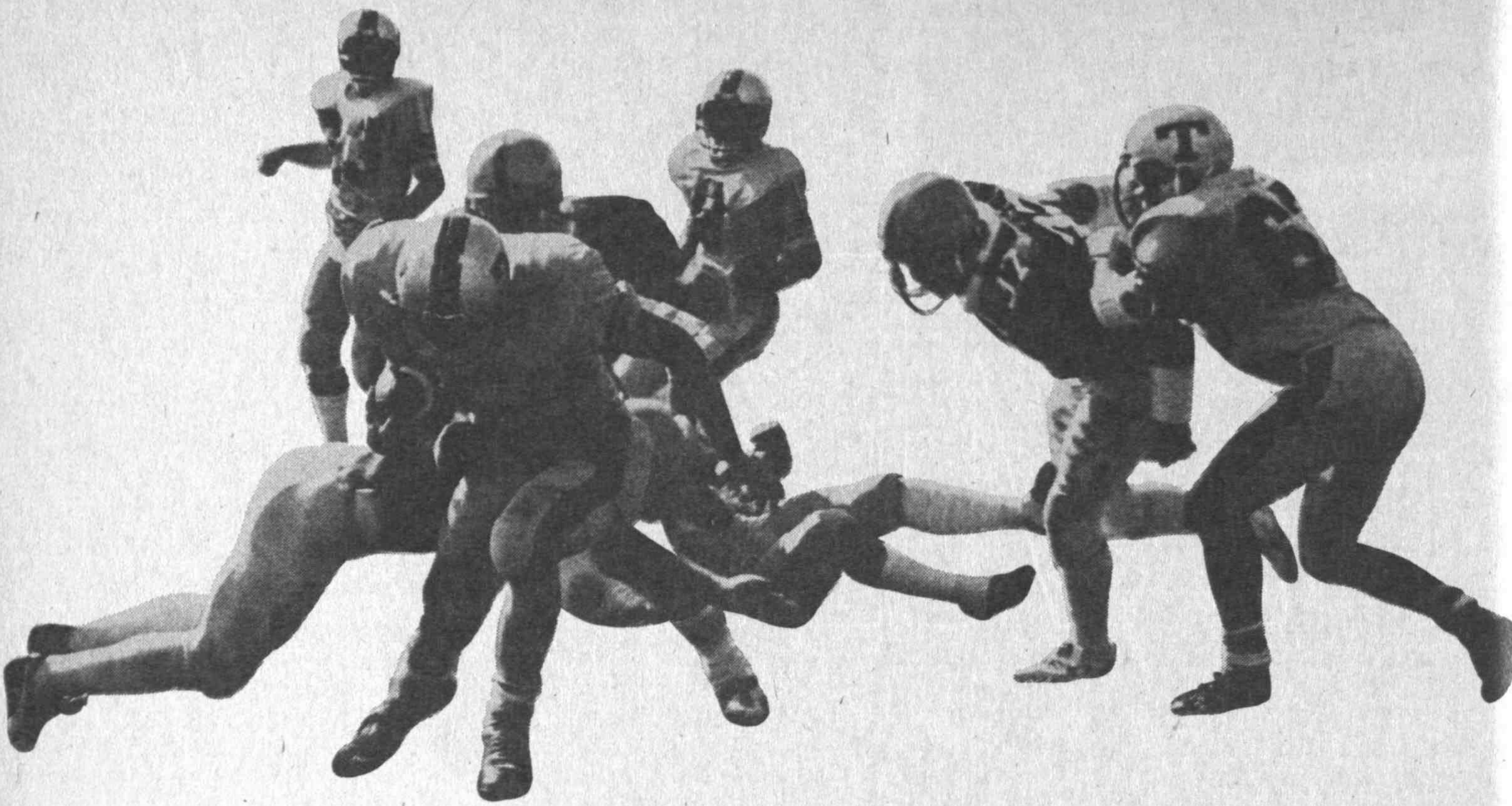
By the same token, microprocessors are reducing the opportunities for product differentiation. If the same microprocessor chip is used in the least expensive sewing machine as in the most expensive one, then features of the most expensive equipment can be provided on the least expensive model at relatively modest cost. As the need disappears for more or higher-quality parts that previously distinguished more accurate and expensive products, how will premium items be made distinct from utility models?

The rapidly increasing application of microprocessors to products and processes will certainly affect competition, which will probably increase from many unexpected sources. Wherever they appear, microprocessors will make the competitive world of the future less certain, less comfortable, and far more exciting.

Robert T. Lund is an assistant director and senior research associate at M.I.T.'s Center for Policy Alternatives. He was principal investigator in the center's study of microprocessor applications and their employment effects commissioned by the British Department of Industry. Marvin A. Sirbu and James M. Utterback also were principals in the study.



The Games Nearly Everyone Plays (see pages A2-A6)



A Daring Concept in College Football: Just a Game We Play

Football at M.I.T.? The idea surprises lots of people, and sometimes there are some not-too-polite snickers. But not from John Powers of the Boston Globe, *who researched the subject at the end of the M.I.T. club's winning 1980 season. Here's his story, reprinted with permission:*

They learn the playbook in a day or so. What are pro sets compared to problem sets? When all the backs were hurt one time, they simply shifted to, well,, let's call it an overloaded right shotgun, and lined up a bunch of people as receivers. Just rearranged the equation.

While certain California universities are trying to figure out how many players it takes to make a speech class, M.I.T. has been using a revolutionary concept in college football, a daring breakthrough. The school plays with whoever wants to show up, average students enrolled in an academic program.

Admittedly, the average Tech student tends to have 750 math boards. Quarterback Barry Jordan, '83, is studying civil engineering. Halfback Fred Allen, '83, is going to be an electrical engineer. There are nine high school valedictorians on this team and a bunch of National Merit Scholars. The M.I.T. offense tends to have a certain precision to it.

They hardly ever go offside or proceed illegally. There is a fine sense of purity about the game here. Tech would rather see its quarterback sacked than be caught holding. "We're the nicest guys you'd want to meet on a football field," testifies placekicker Willy Schwartz, '82.

And quite possibly, unique. The case history of Schwartz, a junior from Paoli, Pa., is nicely representive. He spent his childhood in Lima (Peru, not Ohio) where his father worked for a U.S. firm, discovered American fast food and the English language simultaneously as a grade-schooler, played one game of high school football because the coach had nobody else, didn't realize M.I.T. had a football team and didn't want to come out for it at the beginning.

Now he's something of a legend. As Tech has crafted its first wining season (6-1) in 82 years and is awaiting a playoff invitation, Schwartz has kicked all of the school's 20th-century field goals.

Some explanation is needed here. The student body voted to abolish football in 1900. When the sport was finally revived on a club basis in 1978, Tech found itself without a serious kicker. So field goals were avoided.

Then Schwartz ambled by one day last fall, sidewound a few balls over the crossbar and won the job. People are always ambling by. Tech doesn't bother recruiting; how many prospects out there have 750 math boards, anyway? They just deal with whoever turns up.

"M.I.T. has been using a revolutionary concept in college football, a daring breakthrough: the school plays with whoever wants to show up . . ."

"First day of practice is always a guessing game," nods coach Dwight Smith. "It's 'who are you?' Usually, you're pleasantly surprised."

Great levels of experience are not expected or required here. Most of the M.I.T. varsity played high school ball, but a few are novices. Schwartz was a soccer player until tenth grade, when the structured nature of American sport finally frustrated him. "Back in Peru they put you out on the field and just let you play," he says.

He wasn't playing for anybody when the football coach approached him before the final game of the season. His placekicker, who also played for the soccer team, had a scheduling conflict. Did Schwartz want to give it a try?

For one day? Sure. Mostly, though, Schwartz kicked for fun with his brother Dave, who was the specialist for Yale. When he arrived in Cambridge, he figured there wouldn't be time to play regularly.

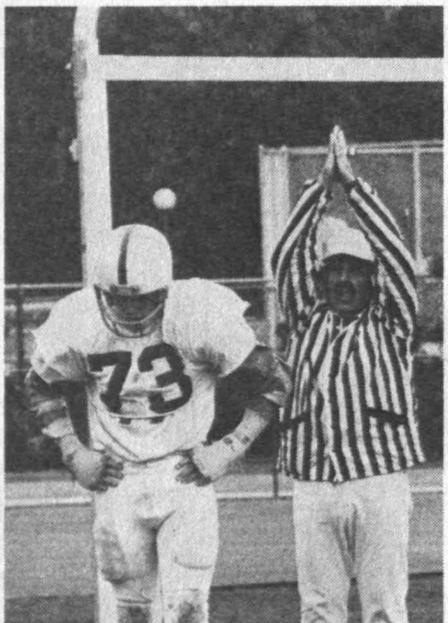
"I was afraid because of the workload," he says. "As I found out, it was a big mistake. Freshman year was my easiest year. Everything was pass-fail. No grades."

Schwartz is majoring in civil engineering, specializing in constructed facilities, a five-year program that will earn him both bachelor's and master's degrees. His day is typically structured and hectic. "Wake up, go to class, go to lunch," he says. "Take a nap before practice, go out for a couple of hours, start studying after supper, go until 2 or 3 a.m."

On road trips, Tech players carry armloads of texts on thermodynamics, physics, and engineering. "When we went to Norwalk, I brought along a book on solar mechanics," Schwartz says. "You have to. You can't waste four hours on a bus. So you tell guys to be quiet and they'll respect that."

Football is a pleasant Spartan exercise they slip in there among all those Athenian pursuits. Some people seem surprised Tech students would want to play this game. More people, including beaten opponents, seem surprised they do it this well. "Against Fairfield we were holding on to a slim 10-7 lead," Schwartz says, "and somebody in their huddle said, C'mon guys, we're getting beaten by a bunch of geeks."

Yeah, yeah. Geeks. Nerds. Gearheads. People figure Tech should be playing Texas Instruments for the national semi-conductor



championship. Even some of their classmates feel that way. If M.I.T. is 6-1, something must be wrong somewhere. "That was the attitude," says Schwartz. "Well, you guys should be playing better teams. Obviously the people you're playing are lousy."

The student body is coming around, though. They had a homecoming weekend last month. A big concert Friday night. A sellout throng in Steinbrenner Stadium Saturday afternoon, with the president roaming the sidelines. Tech crushed Roger Williams, 42-7. People cheered. People got drunk. People enjoyed themselves, for God's sake. There was some campus spirit, some campus unity. Students were actually proud of this team. *The Tech*, the student newspaper, even ran an editorial. "Life passes more pleasantly when you don't despise where you are," it decided. "Few are sorry to see the slide-rule-toting, social-misfit sterotype bite the dust."

Not that this is turning into a jock factory. M.I.T. is happy staying where it is; there's been no upscale talk of going Division 3. The school can play a competitive brand of football as a club team, a good seven-game schedule with uniforms, coaching, game programs, road travel and a national title game to shoot for, all for $8,000 — about what it costs Chuck Fairbanks to panel an office.

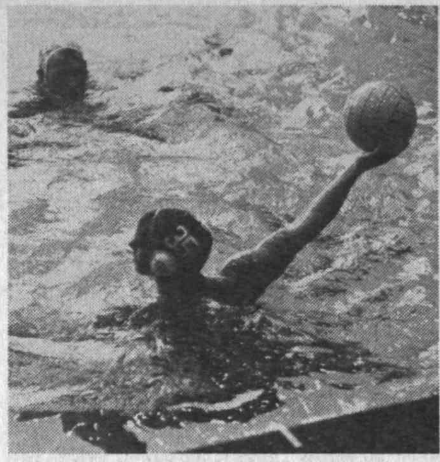
Besides, if it took more than 15 hours a week to do all this, the players would probably have to give the game up. "We had a champagne celebration after the Buffalo State game," Schwartz said. "And suddenly I said, wait a minute, why am I so happy? I have to go back and do two problem sets tonight."

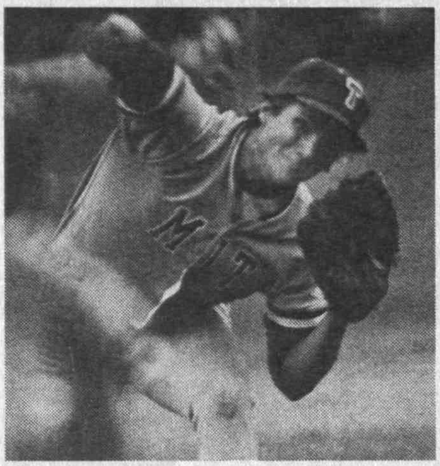
Football has come and gone at this end of the Rivah, but technology is always with them. Practice sessions have to be squeezed between labs and dinner, and almost everybody comes late at least once a week, struggling into jerseys on the run as the autumn sun drops behind the fraternities on Memorial Drive.

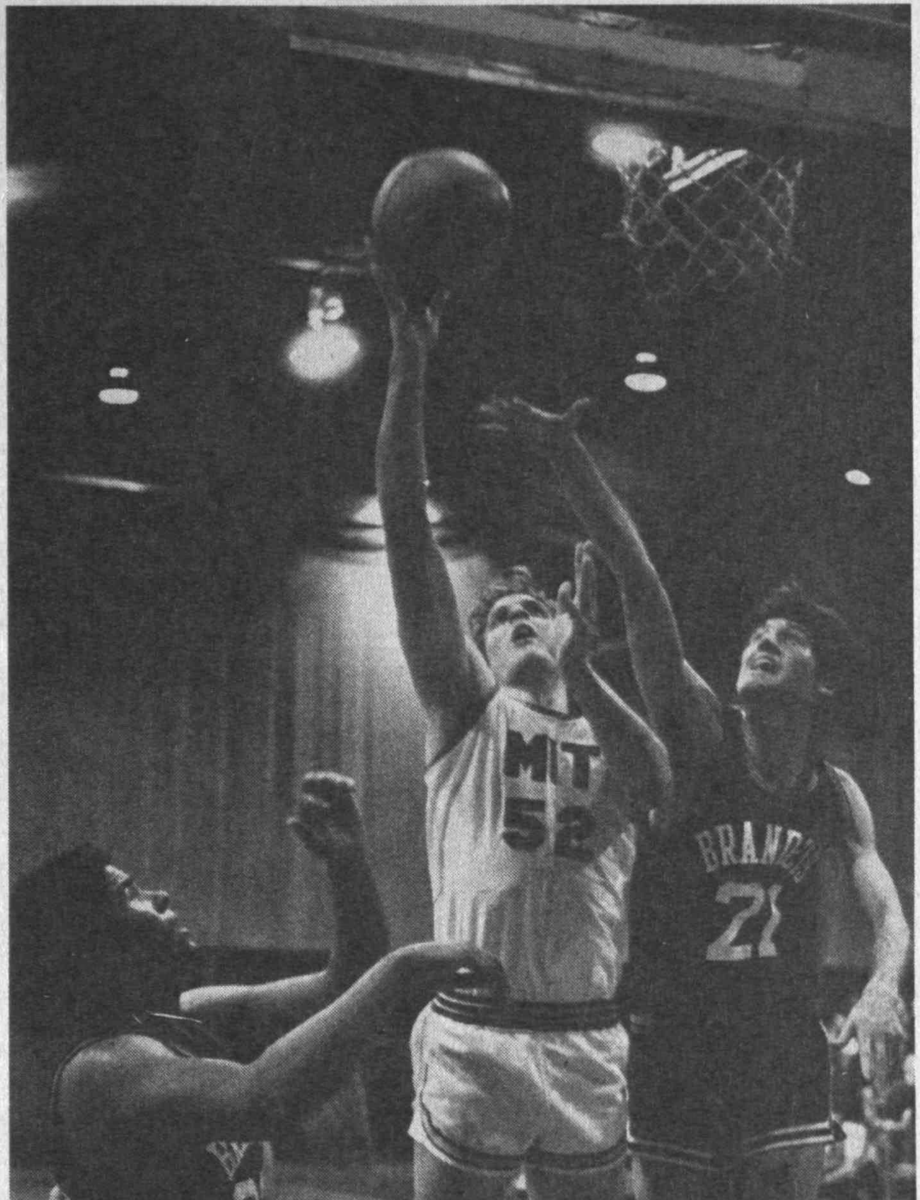
It's easier on placekickers. "I can go out there alone," Schwartz says. "Take my bag of balls, boot 'em through the uprights, go chase 'em."

The games are mostly fun for him. Schwartz has kicked 12 of 13 point-after-touchdowns this fall (actually, he made them all, he says; an official just saw one wrong) and two of four field goals, including a 39-yarder against Fairfield that stands as the school record. He does not seem obsessed with this legacy. "The statistics are just a little toy," he shrugs. "A little game we play."

There will be nothing beyond this, and he knows it. Schwartz will take his degrees and his fluency in Spanish and put up large structures somewhere. He'll definitely turn pro. He just won't be playing ball.







The Games Nearly Everyone Plays

Ross H. ("Jim") Smith's final report as retiring director of athletics last summer was a big one: in 1979-80, over 75 percent of M.I.T.'s 4,500 undergraduates participated in one or more sports programs, 5 percent more than in 1978-79 — a stunning confirmation that the athletics program is fulfilling its major objectives of reaching all students and of introducing them "to life long sports and recreational interests."

Indeed, growth at the rate of 5 percent a year has been characteristic of the last several years of Professor Smith's direction.

Highlights of the report:

☐ More than 1,000 students played in 32 intercollegiate sports in 1979-80, participating in 636 different contests. The 1,000 includes some duplications — students playing in more than one sport. But at least 20 percent of the student body were in intercollegiate competition, Professor Smith said.

Football was part of this intercollegiate action for the first time since 1900. Professor Smith admitted that he and his colleagues first opposed student petitions to add football; they feared its domination of other varsity athletics and saw it as a threat to the balanced athletic program. But it hasn't worked out that way. As John Powers of the *Boston Globe* discovered this fall (*see*

right), M.I.T. plays football just the way it plays everything else — first for fun, then for winning. To prove it, consider this: after a big 6-1 season last fall, the football team was bid by the National Collegiate Football Association to be one of six starters in its national playoffs on November 22 and 29. No dice, said the M.I.T. team; we want that second weekend at home with the Thanksgiving turkey.

☐ Some 11,200 students played on 1,195 intramural teams in 27 sports. That figure, too, includes duplications, but Professor Smith concluded that at least two-thirds of all undergraduates and a "significant" number of graduate students were out for intramurals at least once during 1979-80.

☐ There were just under 6,000 registrations in 57 different courses in physical education — dance, swimming, tennis, fitness and development, skating, fencing, softball, touch football, karate, lacrosse, judo, basketball . . . you name it.

Professor Smith credits the success of the M.I.T. athletic program to its flexibility — activities and facilties keep pace with changing student values — and the emphasis throughout the Institute on informal learning experiences outside the classroom. Six values recommend the program, he says.

☐ Strengthening personal qualities of character and self-discipline.

☐ An opportunity for an outside-of-classroom identification with M.I.T. goals of excellence.

☐ Recreation — relief of stress and improved mental and physical well-being.

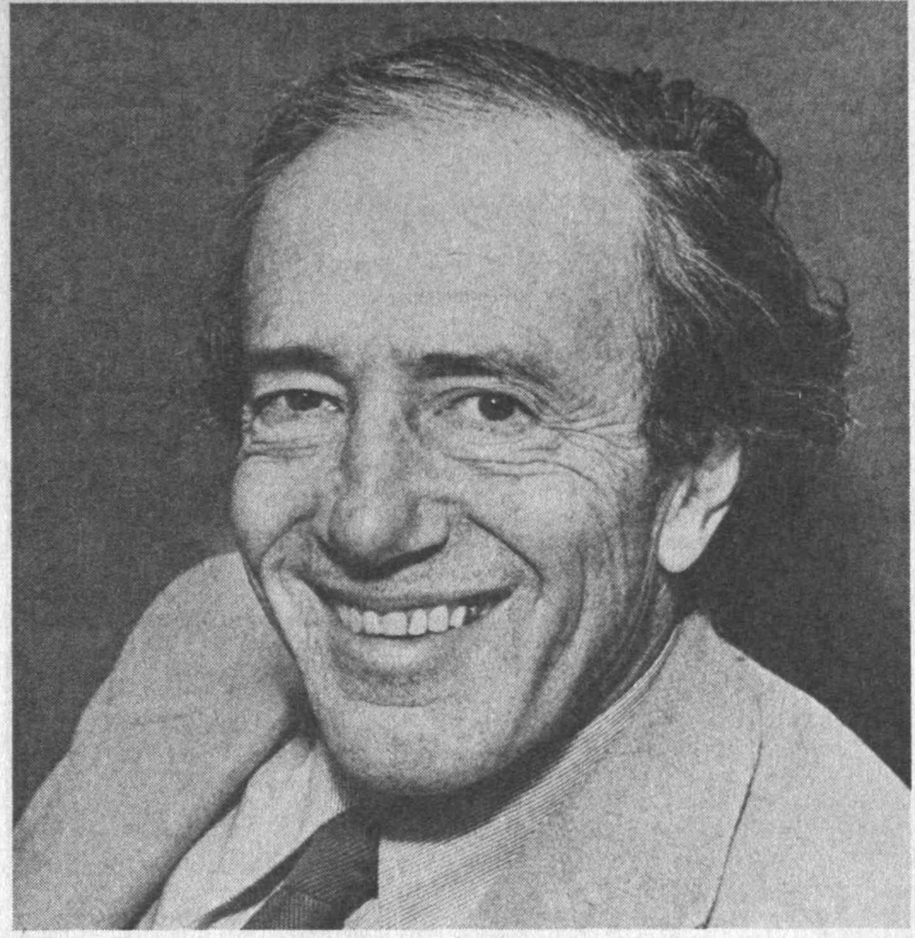
☐ Learning — the idea of preparing for life-long recreational skills.

☐ The experience of give-and-take in competition.

☐ The chance to exert leadership.

Nothing like this ever happens through "formal training in the classroom," says Professor Smith.

As John Powers of the Boston Globe *discovered (see pp. A2-A4), the spirit of amateur athletics which flourishes at M.I.T. is by no means inconsistent with hard, winning varsity play. In a single weekend last fall six M.I.T. varsity teams posted wins: cross-country, field hockey, football, soccer, water polo, and women's volleyball. At the end of the season football received (but rejected) a playoff bid from the National Collegiate Football Association, the cross-country team was invited to the NCAA Division III championships, the sailing team captured the Schell Trophy, women's volleyball tied for third in the state AIAW tournament, three members of the soccer team were named to the Greater Boston all-star team, and David Erickson, '82, was named to the first team of the all-New-England water polo squad. (Photos pp. A2-A6: Kenneth J. Cerino, Albert Allan J. O'Connor, '79, from* The Tech, *James Oker, '81, from* The Tech, *Richard L. Parker from* The Tech, *and James J. Snyder courtesy of* Technique*)*



Francis E. Low as Provost: Less Tennis, Less Family, and Less Sleep — but Plenty of Education

The provost is the senior academic officer, the "number-two man" at M.I.T. who's in charge of the place when the president is away. After six months on the job, what does Professor Francis E. Low think about his metamorphosis from physicist to administrator . . . the offer he "couldn't refuse"?

"You don't really know what something is about until you do it," he said, and then he went on to tell me about it in a quiet, thoughtful way.—*M.L.*

On a Physicist Becoming Provost . . .

From 1946, when I was a graduate student, until January 1979, I did physics as my only professional activity — teaching, consulting, that was it for 33 years. Then the Laboratory for Nuclear Science needed a director and I was invited to fill that role. It was close to my field, and I was able to continue doing physics, although it turned out to be more of a departure than I thought it would be — and more than half time. I enjoyed it; it was interesting to do some research and work as a director, facilitating what other people wanted to do instead of operating alone. So I had already made something of a break from physics — and enjoyed it — when the question came up of my becoming provost. It was also very compelling to be asked by Paul — it was an offer I couldn't refuse.

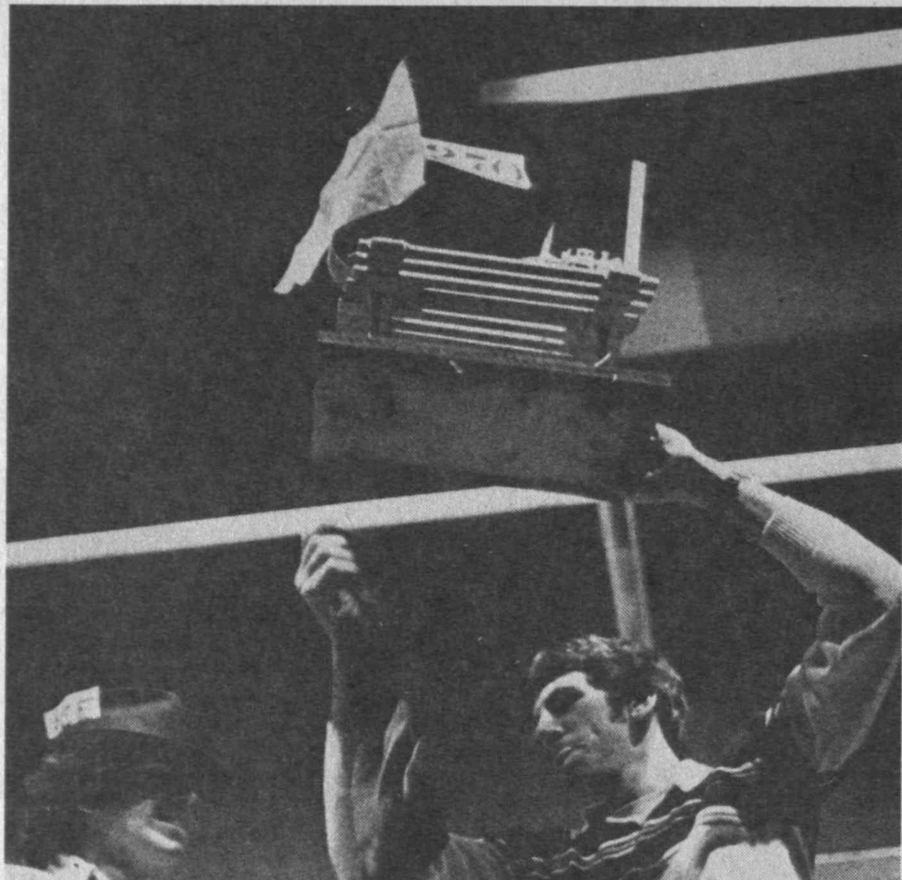
I have no time, now, for physics. But it still has a place in my daily life; if someone talks to me of wing design, I can have at least a qualitative picture of what they describe. This is really full-time in a compelling way (60 or 70 hours a week). I play the piano, and my music has suffered; tennis has suffered, sleep has suffered, family life has suffered. But [he brightens] my wife (a psychologist) can help me with my work for the first time in 33 years.

Research and Teaching . . .

I think of M.I.T. as primarily an educational institution. But to try to separate education and research is difficult; we practice both, and they are inextricably interwoven. We're very much interested in how research affects undergraduate education. In fact, when the question of appropriateness arises for a research policy, we find that a pretty good guide for us — a good *set* to avoid error — is to always ask the question: "What does it do for us as an educational institution?" If the answer is, it doesn't contribute to that, then we should look at it very closely; it's an important test for keeping us honest, and keeping us in the right direction.

Then, given that, it's still true we've become a major research resource for the region, the country, and perhaps the world. One major expansion area now is in microelectronics — very large scale integrated circuits; another is medical sciences, which will be housed in the Whitaker College; another is biotechnology — clearly on a rising curve; another is the plasma fusion effort, driven by the need for large-scale energy sources. All of these correspond to real needs of society or the institution in terms of education. In addition, if there is a need that only we can satisfy, we cannot turn around and say that's too bad, we're not going to do it. Things of national importance we will do, even though they may not be directly relevant to education. Lincoln Laboratories is an example, and there may be others in the future.

I hope we can maintain our academic excellence as a science-and-technology-based university and at the same time be conscious of the strong interaction between science and technology on one hand and social questions on the other. We must let our students take that consciousness into the world — and also contribute, through research, to the amelioration of major problems in society. That is what I would hope — and that is what we're trying to move toward.



Kenneth A. Pasch, '81 (right) calls his first-prize-winner of the mechanical engineering 2.70 Design Contest The Condor. *Robert Di Iorio describes it in* Tech Talk: *"Pasch designed his skinny dipper so that, like a Tasmanian wombat, it launched itself head-first at its target — a tree for the wombat, the swing for the student's machine. Just before impact, the wombat uses its tail to alter its attitude and avoid a head-on collision. It contacts the tree chest first and grasps the limb with its legs. So it was with Pasch's Condor. He used a piece of the rubber tubing for the initial thrust through the air at the swing. The impact with the swing released a second stretched piece of rubber tubing which deployed the two claw-like protuberances that grasped the swing. At the same time the tail end of The Condor was tilted toward the water hole and dug in for leverage."*

Second place went to Michael Kelly, '82 (left). (Photo: Bill Hoffman, '80)

Design Students Enter "A Skinny Dip"

The directions to participants in the "skinny-dipper" contest: "At 7:00 p.m. on October 21 go to 26-100. We must start promptly. Don't forget to bring your 'dipper' even if it is broken, incomplete, or disgusting. You will be expected to place your device on the start area, even if you know it will not work. We encourage you, however, to make it safely do something. If it can do nothing else, have it sink in style."

Some did. And some entries in this year's mechanical engineering 2.70 Design Contest were spectacular. Imagine 26-100 filled beyond capacity with students toting large, strange contraptions, (entrants alone numbered close to 200, and spectators ran rampant) climbing around wildly waving cheerleading tassles (made of strips of computer paper and newspapers) and arms, screaming encouragement or boos, laughing, talking (the noise level is deafening), and working feverishly to put last-minute touches on their projects.

One entry was disqualified (amid booing and hissing) as too dangerous. Thereafter, every time a device sat limply on the platform doing nothing or making a feeble attempt at motion, a voice fervently screamed "Tooooo DANGEROUS!"

The problem: design and build a device which can win a pendulum-pushing contest against another similar device. The pendulum is mounted above a ten-foot-long transparent tank holding approximately three inches of water. The contest is to build a "skinny-dipper" which flies or swims off an 8" x 18" "diving board" at your end of the tank to push harder on the pendulum than your opponent's, coming from the other end of the tank. You have a choice of power sources: a music-box spring, a spring attached to a plastic drum, or an 18-inch piece of rubber tubing. Contests (two dippers face each other with the pendulum in the center) last ten seconds.

In the end — after a long and tough fight, *Condor*, by Ken Pasch, '81, was victorious over *Ace Muff Diver*, by Mike Kelly, '82.

Professor Woodie C. Flowers, Ph.D.'73, in charge of the Introduction to Design (2.70) course, included bits of advice in the students' instructions: "Review the rules. 'I didn't know' doesn't impress the judges." . . . "Remember — hot wires burn fingers and stuff." Lessons applicable to other phases of life. And education at its best.—*M.L.*

Would You Send Your Kid to M.I.T.?

by Steven Solnick, '81

Steven Solnick is a physics major and a former editor of The Tech.

Talking with some friends last week, one jokingly asked, "Would you send your kid to M.I.T.?"

It was a joke to the asker because, although we were all sitting around complaining about our workloads, he actually said he would want his son or daughter to follow in his footsteps.

I've been somewhat obsessed with the question ever since and I've been asking everyone I see. One friend said she wouldn't want her child to go anywhere *but* M.I.T. Another said he'd talk anyone out of going here and if he had it to do all over again he'd stay away himself.

If I had to do it all over again, knowing four years ago what I now know, I'd choose the same school. I'm going to miss M.I.T. when I leave. I expect I'll get a little surge of pride whenever I read about the old Alma Mater. I wouldn't miss my class reunion for anything. I'll probably even donate money if I ever make any.

But I wouldn't want to send my kid here.

It was a real shock for me to say that, but once I realized it there was no going back. I wouldn't talk a stranger out of coming here — I might even recommend it cautiously. I wouldn't talk a friend out of making the trip to the banks of the Charles. But when it comes down to my own flesh and blood, I was surprised to find my insides tense up as I realized I wouldn't trust him or her to come here.

It really is a matter of trust and luck I think. I see my own M.I.T. experience as a thousand or so little accidents most of which turned out for the best. I arrived in Cambridge wanting to be a scientist and I was lucky enough to discover that my true interests pointed elsewhere. I was lucky enough to make some amazing friends and acquaintances. I was lucky enough to become involved in some activities which gave me room and opportunity to grow.

But to do it I had to buck the system. I've told some people that I came into senior year feeling I'd just won a three-year wrestling match with M.I.T. over who would dictate my interests and control my activities. I was *lucky* enough to win the wrestling match . . . I think. I wouldn't feel comfortable trusting my kid to luck out like that.

Time is what it's all about. Who controls your time: you or M.I.T.? There's one key to understanding the ground rules of this little struggle and it stacks the cards against the student from Day 1.

M.I.T. is not an undergraduate institution.

There it is. Heresy, perhaps, but it's the key to understanding this school. I forget who first suggested this interpretation to me but I thank him now in print because it helped me figure out what was so screwed up.

The essence of an undergraduate education is having the time to explore and grow. It's one of the things that makes American higher education unique. Graduate students focus solely on their fields of study; they are researchers, dedicated academics-in-training or scientists-in-training. Undergraduates are the free spirits on the intellectual landscape. That fact should be independent of whether they're scientists-to-be or historians-to-be.

I rode from Boston to New York on Amtrak once with a first-year Harvard Law student. He was a graduate of The College (that's what they call the undergraduate component up the creek). He recounted the time he and his roommate, who edited the *Harvard Crimson*, took three weeks off from classes to follow up some activities of interest to them. He traveled and eventually ended up at Seabrook; his roommate ran the newspaper. They made up the work they missed during Harvard's reading period.

My God, I thought. These guys took a month off without blinking an eyelash. I'd have to plan for weeks to get a free day! Why?

Because the structure of M.I.T. just isn't set up to recognize the importance of anything except the structure of M.I.T. Most students have two or three problem sets due every single week for at least four consecutive terms. A day missed in lab could screw up a schedule for weeks. Attending a lecture at Harvard or Boston University might mean putting off a computer problem and then that delays the paper due for the token humanities course so forget about extra curriculars for now.

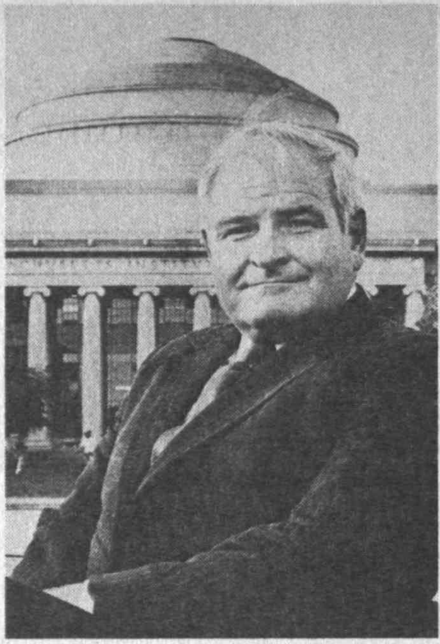
Is that really any way to spend the four most exciting, valuable years of your life, doing fascinating work in your major but never left with the time to consider what any of it means? Wading — as an old teacher once said — chin high in a sea of manure imploring "Don't make waves!"?

When I suggested, at a meeting of students, faculty and administration last I.A.P., that perhaps M.I.T. should consider relaxing its weekly problem set structure to give students a little more time to explore other interests, I encountered a wave of indignation. One department head huffed, "Why, how do you think our undergraduates can compete with *graduate students* anywhere else for jobs?"

Exactly.

One observer at that meeting was now-President Paul Gray, who has spoken recently about reducing the pace of undergraduate life. While he didn't state it as such, I would like to think he means restoring the existence of undergraduate life.

My progeny would like to think so too.



If Engineering Is the Place for Action in the 1980s, Can M.I.T. Survive So Much Success?

"My sense is that M.I.T. in 1980 is . . . the right place to be, the place where the opportunities will be the greatest, where the chances to make a difference will be the greatest."

If, as President Paul E. Gray believes (see page 86), the engineering profession is on the brink of a new era of achievement, can that be anything but a bonanza for M.I.T.?

The answer is that there are both hazards and advantages for the Institute in its present circumstances, President Gray explained to the largest meeting in history of the Alumni Advisory Council on October 27.

But his balance comes out on the positive side. "My sense is that M.I.T. in 1980 is . . . the right place to be, the place where the opportunities will be the greatest, where the chances to make a difference will be the greatest."

Many students clearly read the record as President Gray does. Enrollment in the School of Engineering in the last seven years has doubled, and the best guesses are that the surge will not abate. Indeed, Dr. Gray predicts that these demands will continue throughout this century, perhaps into the next.

Dr. Gray's primary concern is to maintain M.I.T.'s first-rank faculty. But two forces, one economic and one almost psychological in character, make this assignment a tough one.

The economic pressures are strong, and growing stronger. For example, last year U.S. universities produced about 400 Ph.D.s in computer science. The demand across the industry was closer to 1,300 (plus or minus 20 percent) — three times as large as the number available. One result is that the Department of Electrical Engineering and Computer Science (M.I.T.'s largest — it enrolls one-third of the undergraduates) is unable to fill all its openings for assistant professors. "Twenty years ago, even ten years ago, people were standing in line for those jobs," said Dr. Gray. "The reason it cannot fill those positions now is in large measure because of the enormous difference between the economic circumstances of an assistant professor in a first-rank institution like M.I.T. and those of his or her peers in an industrial setting." Similar salary pressures are "a major determinant of faulty morale in other fields as well," says President Gray.

The new psychological pressures are more subtle by far. Research activity at M.I.T. has remained more or less constant in the last ten years in real terms (which means a doubling in dollars.) But that comfortable statistic hides a startling fact: the average research grant has remained about the same size in dollars," said Dr. Gray, "So to have the same level of research activity, a professor has to expect twice as much of all the overhead that goes with it (proposal writing, report writing, and trips to Washington) — all those things that are not productive in terms of research activity itself."

Furthermore, says Dr. Gray, though the facts do not support it, he is convinced there is much more nervousness and competition for tenure at institutions with high standards such as M.I.T. than one or two decades ago. "The probability of getting tenure at M.I.T. for a new assistant professor today is not much different than it was 10 or 20 years ago — it's declined a little, but very little," in Dr. Gray's estimate. But, he says, "the sense of greater competition, of greater risk, and of the need to make increasingly vigorous and strong commitments in order to achieve the objective of tenure is there — no question about it. And this is one of those cases where what matters is not so much the reality but the perception; you have to deal with that perception. It's a major factor in the quality of life as it affects untenured members of this faculty."

In the final analysis, the quality and morale of the M.I.T. faculty is dependent on the continued ability of the Institute to attract the ablest of young people and provide them with the opportunities they need and expect. Just as good students are attracted by a brilliant faculty, so the faculty is attracted by quality in the student body; "those two go together hand-in-glove," he says.

In that sense, the plethora of opportunities that await M.I.T. graduates for the rest of the century works in our favor; in contrast to many other schools, the Institute is unlikely to find its applications declining as the number of college-age Americans decreases during the rest of this decade.

But there are risks here, too. Many youngsters look at the cost of a place like M.I.T. as being just out-of-sight," says Dr. Gray. And he thinks the expectations placed on families "in terms of contributing to college costs, not larger relatively than they were ten or 20 or 30 years ago, are more resented and more resisted now than they were before.

The evidence to date is that cost is not a substantial deterrent in the decisions prospective undergraduate students make about attending M.I.T. But at the graduate level the decision to come here is extremely sensitive to financial aid, and with federal aid declining this presents the Institute with a serious problem.

Yet when all is said, there is one unique quality about M.I.T. that justifies its level of cost. The Institute can put a talented and able youngster in contact with a unique faculty, one on one, throughout his or her educational experience; students can work on research projects beginning as freshmen, through the Undergraduate Research Opportunities Program, and continue with this form of learning through careers as graduate students. So Dr. Gray concluded with almost unbounded optimism: "There is no institution, no organization, no association that is more exciting, more demanding, more likely to be fun than this one is in the 1980s."

Black Students' Conference: African Heritage, Current Problems, Future Course

"To see a black want to come to M.I.T. to get a job saddens me . . . My hope is that some graduates will not take jobs, but begin to create the mechanisms, the organizations, maybe even the government."

"What can we do about the brainwashing that results in our perception of ourselves as second-class citizens who are not quite up to par?" asks a member of the audience at the M.I.T. Black Students' Conference on Science and Technology held here last fall.

The two-day conference suggested that such pervasive insecurity is intrinsic in the black experience in America, and speakers and audience were unanimous in their focus on the need to alter the circumstances that stifle self-expression and demean the goals of blacks everywhere.

"From the outset, blacks were regarded as different," Robert Hayden, director of Secondary Technical Education Programs at M.I.T., told the primarily black audience. He spoke of the black inventors whose achievements could provide an important role model for black children. But they often go unmentioned in our history books. The simple tools of the day designed by slaves were lost because none could be patented. And who ever hears of the contributions of blacks to the American Industrial Revolution after the Civil War? "It's the Real McCoy" refers to an invention of Elijah McCoy, who invented a lubricating cup that fed oil to machinery as it ran. Other examples: a patented stop signal that could be operated unattended (1923); a process that turned sugar cane juice into white sugar crystals and revolutionized the refinement of sugar; a harpoon with a moveable head that would toggle and lock into a whale's flesh (the Temple toggle became universal); an air cooling unit for trucks (1949).

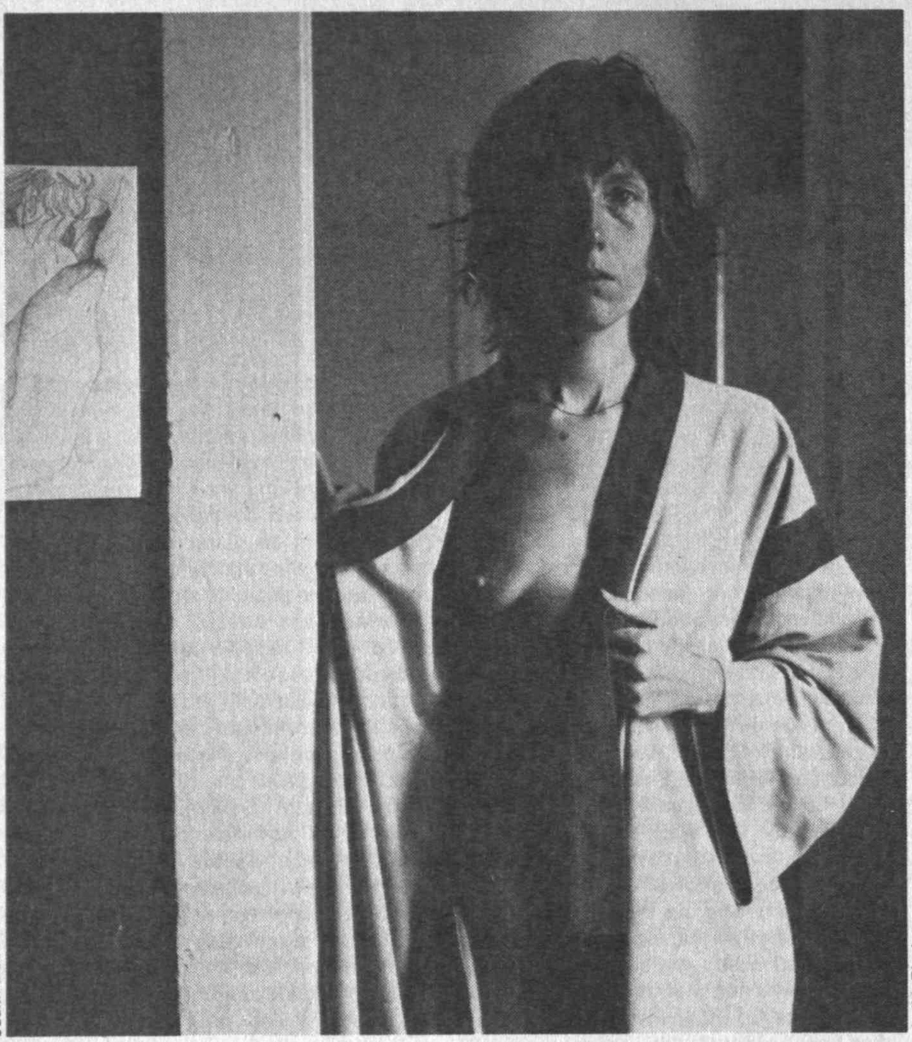
The same kind of achievements can be documented in black Africa. Africans, 15,000 years ago, were the first to cultivate crops. They were the first to consciously use antibiotics, 7,000 years before others. Only two and one-half years ago, scientists discovered that Africans had produced steel 2,000 years ago, using a more advanced method than the Europeans. Unless they are aware of African achievements, said Ivan Van Sertima of Rutgers University (he is editor of the *Journal of African Civilization*), blacks can never have pride in their African heritage. But the pride that Africans should take in their heritage is now clouded by current problems. Only 11 percent of eligible students are in school, said Gayla Cook, '71, director of the Women in Development Program at the African-American Institute. And statistics are worse for women. They tend to drop out at a high rate, she said, and she fears that these downward trends will continue. An example is Zimbabwe: in an extremely self-sufficient and sophisticated economy, with a large requirement for skilled labor, only 14 percent of workers are African (who provide unskilled labor.) Women earn the lowest pay and are the least skilled. Teaching and nursing are the only professional occupations in which women participate, and they are paid much less than men for the same work, she explained.

How to help? Selwyn Cudjo, assistant professor of Afro-American studies, Harvard University, says we should *not* merely export modern technology to Africa. He used the construction of the Aswan Dam as an example to prove his point. "Look at the history of the Nile Valley," he said. "For 15,000 or 18,000 years the center of human development and progress, it was the breadbasket of Egypt. Suddenly, by the 1950s under the influence of Western modernity, it was thought that the river should be dammed. What that did was destroy the Nile's ability to fertilize itself. Silt that before would filter down, now can't. It was the wisdom of the ancient Egyptians that made them *not* dam the Nile; we think they didn't because they couldn't. But they had comparable technology in 3,000 B.C.," he said.

An exploration of history is essential to maintain an identity. But somehow our sights must be raised, says Willard Johnson, professor of political science at M.I.T. "I talk to M.I.T. graduates and they say they want a job. To see a black want to come to M.I.T. to get a job saddens me. I think of a job as another using of your talents. My hope is that some graduates will not take jobs, but begin to create the mechanisms, the organizations, maybe even the government.—*M.L.*

A Master's Degree in Photography as a Mode of Personal Expression

"At the Creative Photography Laboratory one and one don't necessarily add up to two — it's open-ended. There are absolutes in technique but not in image-making," says Professor Starr Ockenga, who is halfway through directing the second year of M.I.T.'s first graduate course in photography (it leads to a master of science in visual studies degree). "We want the students to use photography as a tool — a language to express their feelings and their responses to the world around them. They must master technique (they learn mechanics and craftsmanship first), but the primary goal is to move beyond thinking about technique into thinking about self-expression. They do enough problem sets in the rest of their M.I.T. courses."



Judith Black

Judith Black

Judith Black

Linda Benedict-Jones

Work by graduate students in the Creative Photography Laboratory:

Judith Black turned her camera inward, photographing herself and her four children inside their Cambridge apartment. "The idea for such a venture actually began five years ago, when she photographed herself giving birth to Dylan, her youngest," explains Arno Minkkinen, assistant professor.

Linda Benedict-Jones evolved as a photographer in Europe. She has lived in Portugal, France and England for the last ten years. "More important than knowing where you are going, she seems to be saying in her work, is knowing what you are leaving," writes Professor Minkkinen in Positive, *a student magazine.*

The photography program requires graduate students to take courses, in graphics, environmental art, film/video, and computer graphics as well as in photography. It also offers teaching experience, gallery experience, and now publication experience. Indeed, the goal is to give students the broadest possible range of experience. But the center and core of the program is their own work.

The enrollment is small; when the program is full, there will be ten (five in each year of the two-year program); now the total is five. It's important not to overload the facilities, explains Professor Ockenga, some of which are shared with other undergraduates in the Creative Photography Laboratory.

Research is encouraged. One student is now exploring the longevity of color materials — a much-discussed issue, since dye-based color materials are less permanent than silver-based black and white materials. Another is analyzing the use of photography in the study of architecture.

Assisting in preparation for exhibitions at the Creative Photography gallery allows students to become involved in the whole exhibition procedure from beginning to end. In addition to exhibitions of well-known photographers, shows present lesser-known photographers, and Professor Ockenga says it's exciting to find new young talents.

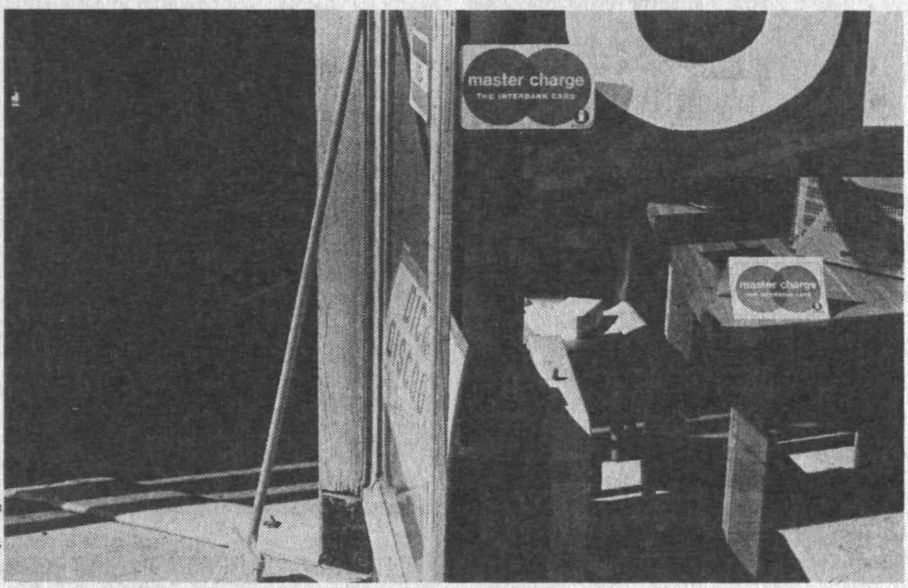
A student magazine, *Positive*, provides a forum for students to articulate their exploration of photography, a place to think about photography and discuss its methods and aesthetics in words.

Future issues will describe photography-related innovative technology, including reports on research projects of the group.

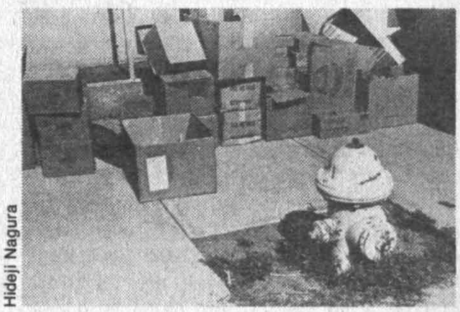
Professor Ockenga, at M.I.T. for five years, has an M.F.A. in photography from Rhode Island School of Design. "I found out there that education is not only education, but it can be *fun*. It's that spirit that pervades the atmosphere here," she says.

But much remains to be done. "A color facility is the next essential step — it is difficult to claim to be a major photographic educational center without a color darkroom," she adds.

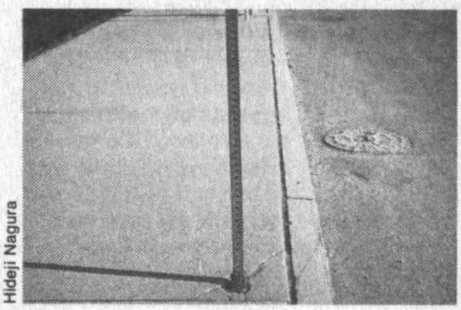
She hopes to interest alumni to support the variety of public (exhibitions and lectures) and educational (research and exploration) activities. She hopes many will subscribe to *Positive*. (It is available for $5.00 through the Publications Program Laboratory of Architecture and Planning, M.I.T. 4-209, Cambridge, MA 02139.) "We want them to be aware that we're a groundbreaking group in an incredibly innovative program," emphasizes Professor Ockenga.— *M.L.*



Hideji Nagura



Hideji Nagura



Hideji Nagura

Robert Alter

Hideji Nagura came to the Creative Photography Laboratory with an impeccable portfolio from Japan University, College of Art in Tokyo. He demonstrated "this uncanny ability to apprehend the absurd," writes Professor Minkkinen.

Robert Alter recently focused his camera on outer suburbia. Now he turns to the city, where homes are vertical apartment houses.

For nearly 60 years since she came to M.I.T. in 1930 with Karl Taylor Compton as ninth president, Margaret Hutchinson Compton was an example of caring and graciousness for all those at the Institute. At the time of her death on November 17, 1980, President-Emeritus Julius H. Stratton, '23, recalled Mrs. Compton as "a person of dedicated concerns, deeply intelligent and keenly perceptive."

Margaret Hutchinson Compton, 1892-1980: 60 Years of Grace and Warmth in Cambridge

Mrs. Margaret Hutchinson Compton, M.I.T.'s First Lady from 1930 to 1949 as the wife of President Karl Taylor Compton, died November 17, 1980, at Massachusetts General Hospital in Boston after a long illness. Mrs. Compton was 88, and she had been a devoted member of the M.I.T. community for nearly 60 years.

Literally thousands of alumni cherish memories of her warmth as hostess in the President's House; her living room was a home away from home for countless students, and faculty and staff have many memories, too, of her and Dr. Compton's hospitality. Only three years ago the Class of 1938 gave funds in her name for a new gallery in the Building 10 Alumni Center; she had been elected an honorary member of the Alumni Association in 1942.

Mrs. Compton's sparkle, energy, and enthusiasm for the interests of students, faculty, and staff continued after Dr. Compton's death in 1954, and for many years she took pride in presenting the Karl Taylor Compton Prizes for outstanding student leadership.

There were tributes from everyone:

□ Howard W. Johnson, chairman of the Corporation: "In her long and extraordinary partnership with Dr. Compton (for 24 years he served as president and chairman of the Corporation), she created a legacy of a nobler, happier, and friendlier environment for living and learning at M.I.T."

□ James R. Killian, Jr, '26, president-emeritus: "She stood as a symbol of the institutional qualities we most prize, and she had a conspicuous success in giving eloquent expression to the aims and values of those of us long associated with the Institute."

□ President Paul E. Gray, '54: "I have never known M.I.T. without Mrs. Compton. She was already a beloved figure when I came to the Institute in 1950 and I have treasured knowing her ever since."

□ Professor Jerome B. Wiesner, president-emeritus: "She was a joyful person, and those about her felt a happiness in knowing her. She had the capacity to convey a special sense of welcome to everyone at the Institute."

Mrs. Compton was born on July 3, 1892, in Minneapolis, Minn. Her father was a professor of Greek at the University of Minnesota, where she graduated in 1914, a Phi Beta Kappa with a degree in anthropology and sociology. She taught for a year in a country school in northern Minnesota, returned to the university campus as the executive secretary of the Young Women's Christian Association, and three years later began traveling to colleges in the Southwest as a YWCA field secretary. During World War I, much of her work was related to wartime service, such as raising funds for canteens.

In 1919 she went to Columbia University for graduate study in philosophy. It was in that year, on a visit to a sister at Princeton University, that she met Dr. Compton; they were married in 1921.

Mrs. Compton took a particular interest in students from foreign countries. She was an organizer of the International Students' Association of Greater Boston and president of the Boston Council for International Visitors.

Margaret Compton's attitude about life was positive and open-hearted, her excitement about science contagious, her devotion to her husband and to M.I.T. complete. "I don't remember the negative," she once told me.— *M.L.*

Anthony Sperduto, 1915-1980

Anthony Sperduto, '42, a long-time member of the research staff in nuclear physics, died on August 14 in Peter Bent Brigham Hospital, Boston, after a long illness. He was 65. He had joined the research staff in the Laboratory for Nuclear Science immediately after graduating and in nearly 40 years had published widely in the field of nuclear physics.

James H. Townsend, 1897-1980

Dr. James H. Townsend, a member of the Medical Department staff from 1960 to 1968, died in Plymouth, N.H., on October 17; he was 83.

A graduate of Harvard (B.A. 1917, M.D. 1921), Dr. Townsend practiced internal medicine with a specialty in diabetes. Before coming to M.I.T. he had been director of professional services at the Boston Veterans Administration Hospital, and after retirement he became a consulting physician in Plymouth.

Donald M. Fellows, 1909-1980

Donald M. Fellows, a laboratory technician in the field of materials science and engineering for 47 years before his retirement in 1975, died suddenly on September 17 in Marlboro Hospital; he was 71.

In addition to his work in metallurgy, Mr. Fellows was well known in the M.I.T. community as a supporter of sailing and a bulwark of the Nautical Association; he was also considered one of the "grand old men" of ice-boating, and he was an enthusiastic photographer and railroad buff.

Kenneth A. Hamilton, 1959-1980

Kenneth A. Hamilton, '81, an undergraduate majoring in computer science, died at the age of 21 on September 30; his death in Somerville was ruled a suicide.

Mr. Hamilton had served as news editor of *The Tech* and had worked part-time in the M.I.T. News Office while on leave of absence as an undergraduate. He had moved off campus shortly before his death, having previously been a resident of East Campus and Bexley.

Bonnie Gresham, 1959-1980

Bonnie Gresham, a Wellesley senior who

was a member of the M.I.T. Reserve Officer Training Corps, died on October 19 in a parachuting accident at Fort Devens; she was 21.

Ms. Gresham was with members of the Trojan Sport Parachutists Club when her chute failed to open after a jump from a private helicopter.

John B. Garrett, 1892-1980

John B. Garrett, '10, who served as a member of the Biology Department briefly after graduation, died in Faulkner Hospital, Jamaica Plain, on October 4; he was 88. Mr. Garrett had been chief bacteriologist for the Veterans Administration Hospital in Tuskegee, Ala., from 1923 to 1954, when he retired.

Ellis C. Littmann, 1910-1980
A Mainstay of M.I.T. in St. Louis

Ellis C. Littmann, '33, a member of the M.I.T. Corporation who through 25 years of involvement with the Alumni Association had become "Mr. M.I.T." in St. Louis, died on November 21 in the tragic fire at the MGM Grand Hotel in Las Vagas. He was accompanied in Las Vegas by his wife Roslyn, who was also a victim of that fire.

"In their passing the Institute has lost a devoted couple whose enthusiasm and dedication to M.I.T. played a substantial role in the advancing of the Institute and its Alumni Association for many years," Howard W. Johnson, chairman of the Corporation, wrote his colleagues. "They will be sorely missed."

Mr. Littman received the Bronze beaver in 1969 for his distinguished contributions to regional conferences, club activities, and Alumni Fund solicitation. He was president of his class and served as its 40th reunion gift chairman: he was active in all of the Institute's major capital campaigns since World War II; and he and Mrs. Littmann wre founding life members of the M.I.T. Sustaining Fellows. The Littmann Scholarship Fund, accumulated by personal gifts and by grants of the Littmann Foundation, is one of the significant endowed scholarship funds at M.I.T.

Mr. Littmann, born in 1910 in St. Louis, studied business and engineering administration at the Institute and promptly joined the Nixdorff Krein Manufacturing Co., St. Louis, where he rose through the ranks to become president in 1954. He finally relinquished that post early this year after serving as the company's chief executive officer for 25 years. The company, with over 1,000 employees at plants in the U.S. and overseas, manufactures chain, wire products, furniture, housewares, and farm equipment.

In addition to his interests in M.I.T., Mr. Littmann was a leader of the Boy Scouts of American in St. Louis, having become an Eagle Scout in 1925. He was also active in professional societies and in Temple Israel, St. Louis.

Dwight C. Arnold, 1905-1980:
M.I.T. Was a Way of Life for 55 Years

Dwight C. Arnold, '27, whose presidency of the Alumni Association in 1955-56 was a highlight of what Howard W. Johnson calls "an unbroken love affair with his *alma mater*," died suddenly in Newton-Wellesley Hospital, Newton, Mass., on November 28. He was 75.

"His love of fellowship and of his fellow humans and his restless itch for activity endeared 'Dike' Arnold to legions of M.I.T. men and women well beyond the campus," Mr. Johnson, chairman of the Corporation, said at a memorial service. "From the day he graduated until the day we lost him, . . . M.I.T. alumni affairs were a way of life."

Harold W. Fisher, the president of Mr. Arnold's Class of 1927, said, "Those of us who knew him well understand the scope and significance of what he did to build an enduring bond of friendship among alumni which will continue for many years."

Upon graduating in business and engineering administration, Mr. Arnold joined a family business, the Arnold Shoe Co., Abington, Mass. Later he helped found the Arnold Copeland Co., manufactureres of metal products, and the Arnold-Stevens Co., maker of electrical instruments; and in recent years he was associated with Kazmer-Standish Consultants in corporate mergers and acquisitions.

Mr. Arnold was a member of the M.I.T. Corporation for five years following his presidency of the Alumni Association, and earlier he had been an active member of the association's Board of Directors and of the Alumni Fund Board and was a principal architect of the annual AOC.

Deceased

Chester A. Brown, '08; June 27, 1980; Langford Apts, P.O. Box 940, Winter Park, Fla.
Charles F. Hobson, '11; September 23, 1980; P.O. Box 1063, Scarborough, Me.
Harold E. Crawford, '13; June 28, 1980; 1324 Isaacs Ave., Walla Walla, Wash.
Robert P. Smith, '13; November 30, 1979; 2861 Monticello Dr., Port Huron, Mich.
H. Whittemore Brown, '15; October 1, 1980; 315 Budd Terr., 1833 Clifton Rd. N.W., Atlanta, Ga.
Clayton P. Hawes, '16; September 1, 1980; 64 Old Westport Rd., North Dartmouth, Mass.
Victor Dolmage, '17; June 1980; 1408 31 St., W. Vancouver BC, Canada
Ronald H. Eaton, '17; September 8, 1980; 24 Church St., Sudbury, Mass.
Archibald B. Johnston, '17; September 18, 1980; Camels Hump Farm, 3765 Christian Spring Rd., Bethlehem, Penn.
Charles E. Plummber, '17; October 23, 1980; 4540 Vandever, San Diego, Calif.
John C. Purves, '18; September 7, 1980; 983 Memorial Dr., Cambridge, Mass.
Joseph G. Higgins, '19; February 1978; 25 Fordham Rd., Allston, Mass.
James W. Reis, Jr., '19; May 30, 1980; P.O. Box 419, Pasadena, Calif.
John B. Garrett, '20; October 4, 1980; 25 Brahms St., Roslindale, Mass.
Raymond C. Reese, '20; May 1, 1980; 3821 Sulphur Spring Rd., Toledo, Ohio.
Melvin R. Jenney, '21; September 29, 1980; 3 Rehabilitation Way, Apt. 706, Woburn, Mass.
Grant L. Miner, '21; September 19, 1980; 829 Laverne Way, Los Altos, Calif.
Kendall Preston, '21; August 6, 1980; Ritz-Carlton, 15 Arlington St., Boston, Mass.
Charles E. Thornton, '21; September 18, 1980; 140 Mill Rd., N. Andover, Mass.
Leo Shedlovsky, '22; August 31, 1980; 210 West 16 St., New York, N.Y.
Frank H. Dillon, '23; September 22, 1980; 28 Gale St., Malden, Mass.
Clayton F. Harvey, '23; July 17, 1980; Philbrick Hall, W. Springfield, N.H.
Anton W. Hosig, '23; October 1, 1980; 424 N. Wood St., Fostoria, Ohio.
Raymond L. Bowles, '24; April 9, 1980; 1115 Wheatland Ave., Lancaster, Penn.
W. Maxey Jarman, '25; September 9, 1980; 4410 Gerald Pl., Nashville, Tenn.
James S. McDonnell, Jr., '25; August 22, 1980; 1 Glenview Rd., St. Louis, Mo.
Roger MacDonald, '26; October 7, 1980; Box 385, Old Turnpike RR 1, Woodstock, Conn.
Harry V. Inskeep, '27; October 6, 1980; 1966 Pennsylvania Ave., Englewood, Fla.
Charles C. Smith, '27; January 7, 1980; 116 Northwestern Ave., Monroe, Ohio.
William E. Gould, Jr., '28; April 9, 1977; Westcott Rd., North Scituate, R.I.
George W. Burgess, '29; October 17, 1980; 1380 Taylor St., Apt. 20, San Francisco, Calif.
T. Bailey Curran, 'September 21, 1980; 81 Mill River Dr., Stratford, Conn.
Vincent F. Damiano, '31; October 21, 1980; 116 Radcliffe Rd., Belmont, Mass.
Leslie H. Reid, '31; August 23, 1980; 24 Franklin St., Box 327, Greenfield, Mass.
Bernard T. Scott, '31; September 18, 1980; 11681 Lake House Dr., Lost Tree Village, N. Palm Beach, Fla.
John K. Campbell, '33; May 1977; 700 Lynden Ave., Arlington Hts., Ill.
Francis E. Cornell, '33; July 30, 1980; 166 Cottage St., Natick, Mass.
Benjamin F. Sands, '33; September 15, 1980; 209 Coburn Woods, Nashua, N.H.
Richard Taylor, '34; June 4, 1980; 27 Garey Dr., Chappaqua, N.Y.
Guy A. Cruse, '35; September 5, 1980; 55 East End Ave., New York, N.Y.
Milton B. Dobrin, '36; May 22, 1980; 2445 McClendon, Houston, Tex.
James E. Acker, '38; January 26, 1980; 172 Yerba Buena Ave., Los Altos, Calif.
J.R. Reynolds, '40; September 22, 1980; 56 Harvard Terr., Gales Ferry, Conn.
Martin B. Levene, '42; October 28, 1980; 469 Brookline St., Newton Center, Mass.
Patrick D. Goggin, '43; August 27, 1980; P.O. Box 150, Kimber Dr. Rd. 3, Phoenixville, Penn.
Arthur W. Plummer, '43; December 28, 1978; Box 797, West Point, Va.
Robert W. Kolb, '46; March 7, 1980; 592 Chelsea Crescent, Beacons Field, Quebec, PQ, Canada
Lucien C. Powell, '46; March 10, 1980; 406 Virginia Ave., Alexandria, Va.
John Bader, '48; September 25, 1980; 500 Treasure Island Causeway, Treasure Island, Fla.
Raymond R. Edwards, '48; May 29, 1980; 1792 Sherry Ln., No. 59, Santa Ana, Calif.
William G. Messimer, '48; June 27, 1980; P.O. Box 469, Sonoma, Calif.
Douglas S. Powell, '50; August 29, 1980; 1340 Watchung Ave., Plainfield, N.J.
Usha K. Bhattacharya, '52; July 7, 1970; Foundries Lab, Tata Loca & Energy Co. Ltd., Jamshedpur, India.
John M. McGrew, Jr., '54; October 16, 1980; 1374 Philomena Dr., Schnectady, N.Y.
Walter M. Schwarzkopf, '57; July 11, 1978; Metallwerk Plansee, A G Reutte/Tyrol, Austria.
Michael F. Garnier, '59; September 24, 1980; 6120 Strelow Ct., San Jose, Calif.
C. Robert Keppel, '59; July 6, 1980; 310 S. 57 St., Omaha, Neb.
Keith P. Kerney, '59; October 8, 1980; 5505 Glenwood Rd., Bethesda, Md.
George E. Ganter, '65; May 22, 1980; 14 Buttonwood Pl., Saddle River, N.J.

Courses

I

Civil Engineering

Bruce S. Smart, S.M.'47, who has been president of Continental Group, New York, since 1975, recently assumed the additional post of chief executive officer. ... **Cordell W. Hull,** S.M.'57, has been named chief financial officer for Bechtel, Inc., San Francisco, Calif. ... **John A. Downs,** S.M.'38, has retired as chief executive officer of Great Lakes International, Inc., Oak Brook, Ill., but will continue as chairman of the boards. ... **T. Robert Kealey,** S.M.'47, reports that he is a managing partner of Modjiski and Masters, specializing in design and construction of long span and moveable bridges in the United States. ... **Arthur R. Anderson,** Sc.D.'35, was named the University of Washington's Alumnus Summa Laude Dignatus for 1980, the highest award bestowed by the Alumni Association. ... Word has been received of the death of **Antonio Barrera Carrasquilla,** Ph.D.'65, of Bogota Columbia, in March 1980.

II

Mechanical Engineering

Norman R. Lampert, S.M.'79, notes that he has transferred from Bell Labs to Southern Bell, Ft. Lauderdale, Fla., as an associate manager, building design and construction. ... **Albert E. Paladino,** Sc.D.'62, writes, "I have recently joined the National Bureau of Standards as deputy director, Office of Energy Programs. ... **John I. Makhoul,** Ph.D.'70, and **William D. Mark,** Ph.D., both principal scientists at Bolt Beranek and Newman, Inc., Cambridge, Mass., have been named divisional vice-presidents.

David Brookstein, S.M.'73, has joined the staff of Albany International Research Co., Dedham, Mass., as a senior research associate. He will be involved with the technology of high-performance fibrous materials and fiber reinforced composites. ... **Richard T. Roca,** Sc.D.'72, has been named head of the Toll Switching Systems, Engineering Department at Bell Labs, Holmdel, N.J., responsible for planning of switching machines used in the toll network. ... **DeWitt R. Petterson,** Sc.D.'59, has been named to the newly created position of executive director of Albany International Co., Dedham, Mass. ... **James E. Acker,** S.M.'38, of Los Altos, Calif., passed away on January 26, 1980. ... **Robert W. Kolb,** S.M.'46, former vice-president and corporation member of Dominion Textile, Inc., Montreal, Quebec, Canada, passed away March 7, 1980. ... The Alumni Association has been recently informed of the death in 1975 of **O. Mauri I. Kurki Suonio,** S.M.'52, of Helsinki Finland.

Fifty years of civil engineering at M.I.T. Above, the department's staff in 1930; below, the staff in 1980.
Above (left to right): row 1 – Babcock, Hosmer, Breed, Spofford, Robbins, Barrows, and Russell; row 2 – Liddell, Howard, Camp, Sutherland, Reynolds, Fife, Gilboy, and Mitsch; row 3 – Wentworth, –, Silverman, Roche, and Mirabelli.
Below (left to right): row 1 – Ashley, Harleman, Manheim, Perkins, Connor, Ladd, Biggs, and Baligh; row 2 – Bjornson, Kausel, Winston, Sloss, deNeufville, Lambe, Whitman, Van Marke; row 3 – Fardio, Levitt, Lerman, Beaker, Marks, Krzysztofowicz, Bras; row 4 – Roberts, Schumacker, Eagleson, Chisholm, Hemond, Marr, and Buyukozturk; row 5 – Cornell, Sheffi, J. Wilson, N. Wilson, Meyer, Morel, Ben-Akiva, and Kaalstad. If readers can put names with the two faces for which they are missing in the upper picture, the Review *will be grateful.*

III
Materials Science and Engineering

Daryl Ann Doane, S.M.'68, a member of the technical staff at Bell Labs, Murray Hill, N.J., has won a Society of Women Engineers' 1980 Distinguished New Engineer Award, in recognition of outstanding technical achievement and leadership. . . . **Jerome B. Cohen,** Sc.D.'54, Frank C. Englehart Professor of Materials Science, Northwestern University, Evanston, Ill., has been named a Fellow of American Society for Metals. . . . **Walter M. Schwarzkopf,** S.M.'57, formerly associated with Metallwerk Plansee, Austria, passed away on July 11, 1978. . . . **Usha K. Bhattacharya,** Sc.D.'52, former chief metallurgist of the Foundry Division of Tata Engineering, India, died on July 7, 1970.

Daryl Ann Doane

IV
Architecture

National recognition came late in 1980 to Childs, Bertman, Tseckares, and Casendino, Inc. (architecture, planning and urban design) of Boston for two projects:

□ From the Masonry Institute of Massachusetts and New Hampshire, a citation for restoration of the 156-foot-high tower of the former City of Boston Fire Headquarters in connection with recycling the building for the Pine Street Inn., a private nonprofit organization which provides food, shelter, and limited medical care to indigent adults in Boston.

□ In the Fourth Urban Design Awards Program for the Urban Design Newsletter, a citation for design of the Clarendon Street Playpark, a community recreational facility at the corner of Clarendon Street and Commonwealth Avenue, Boston.

Maurcie F. Childs, Jr., M.Arch.'60, and **Richard J. Bertman,** '60, are principals in the successful firm.

V
Chemistry

Professors Mark S. Wrighton and Dietmar Seyferth will receive distinguished awards of the American Chemical Society in 1981 — Dr. Wrighton the ACS Award in Pure Chemistry and Dr. Seyferth the award for distingushed service in the advancement of inorganic chemistry. . . . **Paul F. Hogan,** S.M.'68, has been named vice-president in the energy and transportation division at the First National Bank of Boston, Mass. . . . **Ugo R. Nacciarone,** S.M.'60, writes that he is head of the Science Department and senior chemistry teacher at St. Augustine's College, Cape Coast, Ghana, after six years of science teacher training in Nigeria and four years of similar work in Zambia. . . . **Janet Sanford Perkins,** Ph.D.'52, has been honored by the U.S. Army with a Certificate of Outstanding Achievement for her research into the field of high-energy laser radiation and its effects upon various metals.

Kenneth Drake, Ph.D.'55, has been named a research scientist at Union Carbide's Research and Development Department, South Charleston, W.Va. . . . **Arthur B. Ellis,** Ph.D.'77, an assistant professor of chemistry at the University of Wisconsin, has received the second annual Exxon Faculty Fellowship in Solid State Chemistry.

John E. Hallgren, Ph.D.'72, has been named manager of the newly established Polymer Catalysis Project in the Chemical Systems and Reactions Branch of General Electric Research and Development Center, Schenectady, N.Y. . . . **Raymond R. Edwards,** Ph.D.'48, died on May 29, 1980, leaving a long and distinguished record of accomplishments in nuclear chemistry and in international peace; he served as chairman of the Chemistry Department at the University of Arkansas, Fayetteville, and as worldwide ambassador promoting Atoms for Peace . . . **C. Robert Keppel,** Ph.D.'59, formerly on the chemistry faculty at the University of Nebraska, Omaha, died on July 6, 1980.

VI
Electrical Engineering and Computer Science

Professor **L. Rafael Reif,** a native of Venezuela who came to M.I.T. just a year ago after completing graduate degrees at Stanford, is now the Analog Devices Career Development Professor in the department. He'll hold the chair for two years, developing his research and teaching on integrated circuits technology. When the professorship was given earlier this year, **Ray A. Stata,** '57, chairman of the board of Analog Devices, Inc., said the purpose was to "reinforce the capacity and purposefulness of M.I.T. to continue to be a leading educator of versatile people who are potential vital contributors to the high-technology industry in Massachusetts."

Henry Corcoran, S.M.'64, of New Castle, Del., died on February 12, 1978. . . . **Thomas F. Jones, Jr.,** S.M.'40, vice-president for research at M.I.T., has been elected vice-president for public affairs by the American Society for Engineering Education. . . . **John R. Colton,** S.M.'66, is currently supervisor of the terminal design group at Bell Labs, Holmdel, N.J. . . . **Gerald G. Probst,** S.M.'56, has been promoted from group executive vice-president of Sperry Rand Corp., New York City, to president and chief operating officer as well as a member of the board of directors.

VI-A
Cooperative Course In Electrical Engineering and Computer Science

The inauguration of Dr. **Paul E. Gray,** '54, saw a number of VI-A alumni/ae returning for the ceremonial activities of September 24 through September 26, 1980. Director John Tucker co-hosted one of the inaugural luncheon tables along with Professor Emeritus **Karl L. Wildes,** '22, formerly associated with the VI-A program. VI-A's seen taking part in the inaugural procession included: **Richard B. Adler,** '43, associate head of the department; **Cecil H. Green,** '23, life member, emeritus, M.I.T. Corporation; **H. DuBose Montgomery,** '71, chairman of the Alumni Activities Board for the M.I.T. Alumni Association; and **Bruce D. Wedlock,** '56, director, Lowell Institute School and director of patent marketing at M.I.T.

Other attending alumni included: **Michael J. Marcus,** '68, and his wife; **Steven C. Webster,** '78; and **Norman D. (Punsky) Wittels,** '69 and wife, Jill, '70.

Recent visitors to the VI-A Office were **Leonard N. Evenchik,** '77, currently with Bolt Beranek and Newman, Inc., Cambridge, Mass.; **Jeffrey H. Held,** '76, currently with Deal and Associates;

C.K. Colton

Bayer Professorship to Colton

Clark K. Colton, Ph.D.'69, is now Bayer Professor of Chemical Engineering, the holder of a new chair established for a term of five years by a $300,000 grant from Bayer AG of West Germany, a major international chemical firm.

Professor Colton responded to the appointment last fall with a seminar paper on the transport of blood components through membranes, a subject within the field of biomedical engineering in which he is recognized as a pioneer. His work has had impact on studies of artificial internal organs, membrane transport, physiological transport processes, and enzyme technology; his studies of hemodialyis and blood ultrafiltration have been applied to the treatment of kidney failure, and more recent work extends to artificial devices for the treatment of diabetes.

Professor Colton came to M.I.T. after receiving his undergraduate degree in chemical engineering at Cornell in 1964, and he has remained here ever since; he now holds appointments at Massachusetts General and Peter Bent Brigham Hospitals.

Representatives of the main elements of the Bayer organization in the U.S.— Cutter Laboratories, Inc., Miles Laboratories, Inc., and Mobay Chemical Corp.—joined a group from the Bayer headquarters at the seminar presentation.

Alan M. Marcum, '78, with Hewlett-Packard Labs, Palo Alto, Calif.; and **Ernest D. Vincent,** '72, consulting engineer.— John A. Tucker, Director, Course VI-A, Room 38-473, M.I.T., Cambridge, MA 02139

VII
Biology

Edward Carr Franks, S.M.'76, has received a doctoral degree in policy analysis from The Rand Graduate Institute, Santa Monica, Calif.

VIII
Physics

David Rose, Ph.D.'50, reports that commencing January 1, 1981, he will be taking up a joint appointment with the East-West Center, Honolulu, Ha. He is also serving on the program committee for the International Energy Symposium Series of the 1982 Worlds Fair, Knoxville, Tenn. . . . **Robert N. Noyce,** Ph.D.'53, has received the Moore School of Electrical Engineering's Harold Pender Award at the University of Pennsylvania, in recognition for his outstanding contributions to society in the engineering profession.

X
Chemical Engineering

Hoyt C. Hottel, S.M.'24, professor emeritus of the department, received the 15th National Academy of Engineering Founders Award, the society's highest honor. . . . **Pieter Stroeve,** Sc.D.'73, reports that he has been promoted to associate professor of chemical engineering, with tenure, at the State University of New York, Buffalo.

Martin A. Welt, S.M.'57, is current president and chief executive officer at Radiation Technology, Inc., Rockaway, N.J. . . . **Gerard C. Coletta,** S.M.'68, corporate director of safety, National Semiconductor Corp., Santa Clara, Calif., has been elected chairman of Committee F-23 on chemical protective clothing of the American Society for Testing and Materials. . . . **Arthur W. Plummer,** S.M.'43, of West Point, Va., died on December 28, 1978.

Karl F. Cast, S.M.'41, has been promoted from general manager, engineering, central systems and data processing at the Ethyl Corp., Richmond, Va., to vice-president of these departments. . . . **Irwin Gruverman,** S.M.'55, has been elected executive vice-president — operations, of New England Nuclear, Boston, Mass. . . . **Robert M. Cornforth,** S.M.'37, writes, "I recently retired (for the second time) and will continue to live in Houston, mainly because my son and three grandchildren are also here."

XII
Earth and Planetary Sciences

Robert M. Stesky, Ph.D.'75, writes, "I am presently an associate professor of geology at Erindale College, University of Toronto, Mississauga, Ontario. I received tenure in 1979 and am now engaged in research into the geophysical properties of fractured rock." . . . The Alumni Association has just been informed of the death in 1972 of **Christopher K. Bell,** Ph.D.'53.

XIII
Ocean Engineering

William M. Nicholson, S.M.'48, has retired as director of the Office of Ocean Technology and Engineering Services, National Oceanic and Atmospheric Administration. . . . **Robert I. Price,** '53, commander of the Coast Guard Atlantic Area and of the Third Coast Guard District, was presented with the Distinguished Service Medal by the U.S. Coast Guard for "outstanding professionalism and political acumen." . . . **John Isaac Hale, Sr.,** S.M.'20, a former production officer at the Portsmouth, N.H., Naval Shipyard, died in June 1980. . . . **Spencer Reitz,** S.M.'48, has been appointed deputy general manager of Electric Boat Division, General Dynamics Corp., Groton, Conn. . . . **Robert J. Esslinger,** S.M.'40, of Walnut Creek, Calif., died on August 21, 1980. . . . **James R. Reynolds,** S.M.'40, former supervisor of contruction and repair of nuclear powered submarines at General Dynamics-Electric Boat, died September 22, 1980.

A Professorship for Applied Geology

Gifts from the Kerr-McGee Foundation, Inc., and the Kerr Foundation, Inc., both of Oklahoma City, have established the Kerr-McGee Career Development Professorship for a junior faculty member in the Department of Earth and Planetary Sciences. The new program — an opportunity for a younger member of the faculty to enhance his or her research and teaching skills in a new arena — will significantly help the department strengthen its activities in applied geology and geophysics, according to Professor Carl I. Wunsch, '62, head of the department.

Breene M. Kerr, '51, former president of the M.I.T. Alumni Association who is now a member of the Corporation, is a director of Kerr-McGee Corp. His associate, Dean A. McGee, chairman and chief executive officer of that company, has also been active in M.I.T. affairs.

XIV
Economics

William H. Miller, '42, of Toledo, Ohio, died May 6, 1977. . . . **Theodore W. Zetterberg,** '52, writes, "I am enjoying better health and fitness here in sunny California (Menlo Park)." . . . **Halbert White,** Ph.D.'76, a member of the economics faculty of the University of California, San Diego, has created the HLW Consulting firm, designed to do econometric forecasting of gold prices. . . . **Myra H. Strober,** Ph.D.'69, writes, "I have been promoted to associate professor at the Stanford School of Education and associate professor of economics (by courtesy) at the Stanford Graduate School of Business. I also serve as director of the Stanford Center for Research on Women."

Arthur G. Ashbrook, Jr., Ph.D.'47, reports that he has been working with the CIA for 25 years and is currently "on loan" to the National War College at Fort Lesley J. McNair, Washington, D.C. He has also published a number of articles on the Chinese economy. . . . **George W. Shuster,** S.M.'69, has been appointed vice-president and general counsel of Cranston Print Works Co.

Managerial Ideas, not Pharmaceutical Miracles, to Cure America's Ills

Is the U.S. losing its world economic primacy?

By many measures, yes: productivity growth is down, our ability to compete with foreign manufacturers, even using our own technology, is in doubt, inflation is rampant, our balance of payments is wrong.

Faced with these issues, says Willard D. Butcher, president of the Chase Manhattan Bank, American business spends too much time looking for a miracle cure — a universal antibiotic that will relieve us of all our present traumas quickly and simply.

The quest misses the point. "We need nothing less than a major and sustained effort in the marketplace of ideas," Mr. Butcher said in keynoting the biennial Sloan Fellows Convocation at M.I.T. on October 3.

It was just 50 years ago that Alfred P. Sloan, Jr., '95, then president of General Motors Corp., had brought a similar view of management imperatives back to his *alma mater*, persuading President Karl Compton, Professor Irwin H. Schell, '12, and other members of what was then called the Department of Business and Engineering Administration to prepare an intensive one-year backgrounder in management studies for young executives. The result, of course, was the Sloan Fellowship Program; and this fall, 50 years after its founding, several hundred of the program's alumni returned on October 2 to 4 to sip again at the fountain they had tried to tame as fellows.

"Participation in the idea marketplace should be a living, breathing part of everything we do in our business lives," Mr. Butcher said; the business leader of the 1980s must be "a liberally educated person of affairs, who understands history, psychology, economic theory, and societal forces at work in the world."

Oliver C. Boileau, Jr., S.M.'64, president of General Dynamics Corp. who shared the platform with Mr. Butcher on October 3, agreed. "The risk-takers who built our industrial might have been replaced by business-school bean-counters apparently more interested in short-term gain than in long-term goals," he said. "Our conservatism is killing us. . . . In the decade ahead, American industry's two greatest problems are not productivity and quality but arrogance and fear."

Entering the Marketplace of Ideas

Is American really on the decline, forced to its knees by its own inability to see what is happening and respond, by its declining productivity, deteriorating spirit of innovation, and depleting energy resources? The convocation dialogue made the downhill slope seem very real; and "there are no living examples of a society that has pulled itself together after a slow decline," Mr. Butcher warned — not the Greeks, not the Romans, not the British Empire after World War I.

Part of the trouble is that change comes on us not as a moment of crisis but as a continuing, almost imperceptible drift; and under these conditions managing change to turn adversity into advantage is a very special administrative challenge.

If the U.S. is to succeed in this task, said Mr. Butcher, business managers must apply the same sophistication, discipline, resource commitment, and courage in the marketing of ideas as they apply in the marketing of products. . . . Participation in the idea marketplace should be a living, breathing part of everything we do in our everyday business lives."

When its alumni returned to Cambridge last fall to celebrate 50 years of the Sloan Fellowship Program, they saturated the ballroom of the Copley Plaza (top), met old friends (center: Dean Emeritus E. P. Brooks, '17, with John M. Wynne, S.M.'56), told the faculty a thing or two about the real world out there, and (opposite) listened to a distinguished panel of fellow-workers in the vineyard of the not-so-thriving U.S. industrial machine. (Photos: Bradford Herzog)

Programming Growth for the Sloan School

The Sloan School of Management — "clearly the leading school of management in its concern for the management of technical enterprise," says President Paul E. Gray, '54 — is on the edge of significant expansion, a planned growth in enrollment, research, and facilities.

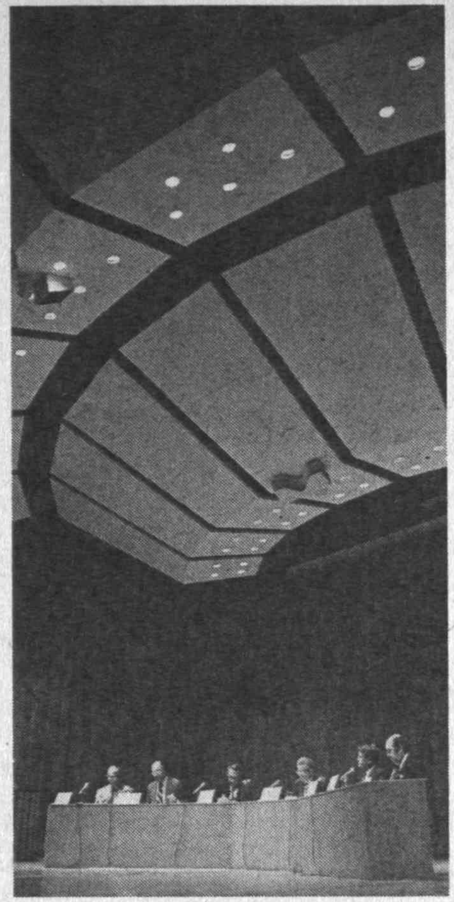
□ By 1984-85 the school is to be serving 850 students, a 30-percent increase over current levels. (That number includes students in the school's own major programs and students from other M.I.T. schools taking one or more management courses.) The major change will be in the school's two-year master's program, where enrollment will grow from 200 to 300.

□ Larger student enrollments will be accompanied by faculty expansion — about 30 percent.

□ There will be a new one-year (accelerated) master's program in management and engineering, designed expressly for students with background and experience in engineering to learn management principles.

□ The school's research program will nearly double in size by 1984-85 — from $2.5 million this year to $4.5 by 1984-85.

□ The first phase of a two-phase program to expand and renovate the school's facilities is now under way at 70 Memorial Drive, the Sloan Building's neighbor which originally housed National Research Corp.



Building a New China Connection in Management

At first glance it is at least incongruous, almost inconceiveable: the world's largest (and most isolated) Communist economy coming to the U.S., the world's largest capitalist economy, for lessons in management. But it's been happening since 1978, and the Sloan School of Management has had a leading role in expediting this unlikely but growing international exchange.

The first overtures from U.S. management brought 18 top-level Chinese to the U.S. in 1978 to visit five leading management schools — Harvard, Stanford, Wharton, and the University of Indiana in addition to M.I.T. The experience generated "enormous good will" on both sides, says Professor Richard D. Robinson of the Sloan School; he still remembers his "surprise at how easily the Chinese accepted everything," he told Sloan Fellows back for their 50th anniversary biennial conference last fall.

The Chinese came because they regarded U.S. management skills as "preeminent in the world," a useful model therefore for the Chinese to understand, Professor Robinson said. They expected to find computers and management information systems the essential tool of this system, and they were unprepared to hear their U.S. hosts talking so much about interpersonal skills, communications, marketing, and even finance.

XV
Management

Peter P. Gil, associate dean of the school, has been elected chairman of the trustees of the Cambridge Hospital and Neighborhood Health Centers. ... **D. Bruce Peterson,** S.M.'70, has been named senior vice-president of TMI Systems Corp., Lexington, Mass. ... **Richard Carrion,** S.M.'77, is presently senior vice-president for finance and operations at Banco Popular, Puerto Rico's largest bank. His present preoccupation is to determine the cost-effectiveness of expanding the bank's computer operations, already the largest on the island.

Robert Moser, S.M.'74, has been named president of the American Fine Wire Corp., Selma, Ala., manufacturer of semiconductor bonding wire and other specilty wire items. ... **Birgul Erengil,** S.M.'75, writes, "I have started a new company called Boston Planning Group, Inc., in December, 1970. The firm provides computer-based products and services in the corporate and financial planning area." ... **William G. Messimer,** S.M.'48, of Sonoma, Calif., died on June 27, 1980. ... **Newmann M. Marsilius,** S.M.'42, has been honored by membership into the Free Enterprise Hall of Fame, an honor roll of business leaders in Western Connecticut.

Sloan Fellows

Sam R. Willcoxon, S.M.'65, is now vice-president — network operations for the American Telephone and Telegraph Co. Long Lines Department, Bedminster, N.J., having moved last August 1 from the post of vice-president — business for the Pacific Telephone and Telgraph Co. ... **Hugh E. Witt,** S.M.'57, is now vice-president — government liaison of United Technologies Corp., a new position based in Washington, D.C. ... **Nathaniel S. Howe,** S.M.'62, who has been corporate vice-president and group executive of Litton Industries' metal cutting divisions, is now chairman of the New Britain Machine division with additional duties at the Litton Machine Tool Systems group. ... Formerly president of Sun Oil Trading Co., **Gordon S. Cochrane,** S.M.'67, is now vice-president — lubes marketing for Sun Petroleum Products Co. ... Dr. **Thomas A. Helmrath,** S.M.'77, has joined the Ohio Board of Regents as vice-chancellor — health affairs; before August 1, 1980, he was associate dean for clinical services at the College of Human Medicine, Michigan State University. In his new job Dr. Helmrath has charge of a statewide system that includes seven medical, nursing, veterinary, optometry, and health technology education programs.

Word has been received by the Alumni Association of the death of **George E. Ganter,** S.M.'65, of Upper Saddle River, N.J., in May, 1980.

Senior Executives

Bart A. DiLiddo, '74, has been named executive vice-president of B.F. Goodrich Co. and head of its Chemical Group. ... **Richard M. Osgood,** '59, previously vice-president — planning and business development for GTE Consumer Electronics, is now vice-president — business development of General Telephone and Electronics Corp. ... **Seymour Orlofsky,** '60, retired from the Columbia Gas System, Inc., Wilmington, Del., last July 31.

XVI
Aeronautics and Astronautics

Joseph Mallen, S.M.'48, has been named president of Boeing Vertol Co. ... Professor Rene H. Miller and **Daniel J. Fink,** S.M.'48, were made honorary fellows of AIAA at the association's Global Technology 2000 meeting in Baltimore, Md., last May. ... **C.A. Easterling,** S.M.'64, has been appointed commander, Battle Force Sixth Fleet, U.S. Navy. ... **Harold W. Smith,** Sc.D.'61, reports, "I returned to teaching and research as professor of electrical engineering and professor of metallurgy and materials science (a strange fate for Course XVI graduate) after four years as vice-dean of the graduate school and a year's research leave profitably spent in Australia. I am still at the University of Toronto, of course." ... **Marc P.L. Genain,** S.M.'75, reports that he is working for the Caracas subway system as chief engineer for operations. ... **Keith P. Kerney,** '59, of Bethesda, Md., died on October 8, 1980. ... **Lucien C. Powell,** S.M.'46, of Alexandria, Va., died on March 10, 1980. ... **Richard J. Schulte,** S.M.', has been elected a vice-president of Stone and Webster Management Consultants, Inc., New York, N.Y.

Albert C. Hersom (left), research director of Londreco, Ltd., London, has now presided over seven editions of his book, Canned Foods: An Introduction to Their Microbiology. *"Anyone who can keep a book current through seven editions has got something going for him," says President Paul E. Gray, '54. What Mr. Hersom has going for him is the eighteenth Underwood-Prescott Memorial Award of M.I.T., given to him this fall for "leadership in food microbiology and canning technology." Presiding at the award luncheon, James D. Wells, president and chief executive officer of the William Underwood Co., said the program is an example of the industrial-academic cooperation which will be required "to meet the challenge of feeding the world population in the coming decades." (Photo: Calvin Campbell)*

XX

Nutrition and Food Science

Professor **Steven R. Tannenbaum,** Ph.D.'58, received the 1980 Babcock-Hart Award of the Institute of Food Technologists for contributions to food technology that have improved public health through more nutritious food.

Technology and Policy Program

Amarquaye Armar, S.M.'78, recently served as panel member during the M.I.T. Black Students' Conference on Science and Technology. He is currently working as the assistant to the science and technology advisor at the World Bank. . . . **Robert Chen,** who entered TPP in 1978, married Meredith Golden this summer in Vermont and is working for the Climate Research Board, National Academy of Sciences.

Two more former TPP students are working in Washington, D.C. area: **Michale Karma,** S.M.'80, for the Office of Program Analysis and Evaluation, of the Defense Department, Arlington, Va.; and **"S.K." Sarvadevabhatla,** S.M.'80, for ICF, Inc. . . . **David Hanrahan,** S.M.'79, is employed by a civil engineering firm in South Melbourne, Australia, and writes that he is enjoying the skiing and yacht-racing there. . . . **David Kagan,** S.M.'80, is in Reading, Mass., working for TASC. He spent three weeks backpacking in the Canadian Rockies this summer.— Professor Richard de Neufville, Chairman, Room 1-138, M.I.T., Cambridge, MA 02139

Michael Taviss, '81, wrote in The Tech *that the M.I.T. Musical Theatre Guild's "Cabaret" — the fall, 1980, production — was "perfectly marvelous." But true to his M.I.T. perspective, he liked her (Theresa Muller) better than him (Marcus Filipovich, '81, playing Clifford Bradshaw). "To anyone who is hunched over a desk tooling," Mr. Taviss' advice: "What good is sitting alone in your room? Come hear the music play . . ." (Photo: Richard L. Parker from* The Tech*)*

Sustaining our reputation. M.I.T. is one of the most productive stops for the Red Cross Bloodmobile in New England, and President Paul E. Gray, '54, wants to keep it that way. He was among the first donors in a record-breaking week in the Sala de Puerto Rico in November. (Photo: Steven Cohen, '84, from The Tech*)*

The Smoot Bridge? Well, Yes, They're Serious

Though its called the Harvard Bridge, it's between Boston and M.I.T.— "nowhere near Harvard," says Peter Balbus, '81, arguing for a more appropriate and less confusing nomenclature.

Mr. Balbus organized a non-binding straw poll late last fall to sample student opinion on several alternative names — the Beaver Bridge, the Institute Bridge, Smoot Bridge, the William Barton Rogers Bridge, the Cambridge Bridge, Richard Cockburn MacLaurin Bridge . . . Furthermore, he's lobbied with considerable success on Beacon Hill, and he thinks the name change may well come up for enactment in the legislature as early as February.

And then, says Mr. Balbus, there should be a ribbon-cutting ceremony, for which Oliver R. Smoot, Jr. '61, will be an honored guest, no matter what name the bridge is finally given. It was Mr. Smoot's height that became the traditional unit of measure for the length of the bridge after a Lambda Chi Alpha pledge week caper in 1957, and now every fall the markers for the 364.4 Smoots between Boston and Cambridge are repainted by Lambda Chi Alpha's new pledge class.

Dreaming the Unthinkable

The newest among more than 100 M.I.T. student activities: the Investment Analysis Society. Calling undergraduates to attend their first meeting last fall, charter members of IAS engaged in a bit of fantasizing: ". . . Wondering what to do with extra cash . . . left over from your tuition payment or selling your Jaguar?" they asked.

Among Those Honored

President-Emeritus **Jerome B. Wiesner** was chosen by the Franklin Institute for its Delmer S. Fahrney Medal for "outstanding leadership in science and technology." Dr. Wiesner was cited for "his unyielding sensitivity to human values and the public interest in the utiliziation of science and technology." . . . In selecting Professor **Lawrence R. Klein**, Ph.D.'44, of the University of Pennsylvania to win the 1980 Nobel Prize in economics, the Nobel jury was also honoring M.I.T.: Professor Klein holds the first Ph.D. ever given by the Institute in economics. Professor Paul A. Samuelson, who won the Nobel Prize in economics in 1970, was Professor Klein's adviser for his thesis, an analysis of the theories of John Maynard Keynes which gave a preview of its author's ability to apply higher mathematics to economic analyses. "We're proud of him," said Professor Samuelson with a bit of dry understatement when the selection was announced last fall.

Sponsored Research Forecast: $177.5 Million, Up 17 Percent

On-campus sponsored research will be up by nearly 17 percent in 1980-81 over 1979-80, according to forecasts by Robert M. Dankese, associate budget director. This year's on-campus sponsored programs will be $177.5 million (excluding major subcontracts) compared with last year's $151.8 million.

Lincoln Laboratory's volume, excluding sub-contracts, will be $135.9 million in 1980-81, up 11 percent from $122.3 million last year.

By far the largest single forecast increase is for the Plasma Fusion Center, whose volume will rise from $9 million to over $15 million, according to Mr. Dankese. Increases in the $1-million range are forecast for the Center for Policy Alternatives; the Departments of Biology, Earth and Planetary Sciences, and Physics; the Cell Culture Center; the Harvard-M.I.T. Division of Health Sciences and Technology; Haystack Observatory; the Laboratory for Nuclear Science; and the Research Laboratory of Electronics.

Seventh in Professors' Salaries

M.I.T. ranks seventh among major educational institutions in the U.S. in average salaries paid to full professors in 1979-80, according to figures compiled by the American Association of University Professors from data collected by the National Center for Education Statistics.

The Institute's average full professor received $43,900, including both salary and fringe benefits adjusted to a nine-month basis, according to the compilation published in *Chronicle of Higher Education*. Higher-ranking institutions included Rockefeller University ($50,500), Harvard ($47,200), Columbia ($46,200), Stanford ($45,200), the University of California at Berkeley ($44,800), and the University in San Franciso ($$44,300). Following closely after M.I.T. came the State University of New York at Stony Brook ($43,300), California Institute of Technology ($42,700), Chicago ($42,500), Pennsylvania ($42,200), and Yale ($41,900).

Other averages reported for M.I.T. included $29,700 for associate professors, $23,200 for assistant professors, and $20,200 for instructors. The *Chronicle* said that average salaries in private institutions were 8 percent higher in 1979-80 than in 1978-79.

Riding Again After 50 Years

For the first time in more than 50 years, riding is a recognized student activity at M.I.T.

Enthusiasts rallied by Karen Hensley, '81, have formed the M.I.T. Equestrian Club and arranged to ride regularly from the Elmbrook Farm in Concord. If all goes well, they hope the club can buy its own horses and thus be able to give instruction, for which physical education credit will be offered. The precedent was set in 1928, when a number of students joined to lease horses and play a spring polo schedule.

The 33rd Mexican Fiesta

Bienvenidos! to at least 100 alumni in Mexico City on March 13, the rallying point for the 33rd annual M.I.T. Fiesta. The program combines the archaeological and colonial jewels of Mexico City, Cuernavaca, and Taxco with multiple "get-togethers."

Formal events begin on March 14 with a half-day excursion to Teotihuacan and Citadela, followed by an evening Fiesta Mexicana. The program for March 15 includes the Ballet Folklorico or an optional archaeological tour, followed by an after-

The McCurdy part of the name is familiar enough, and so is the figure at the right in the picture – that of Horace W. McCurdy, '22, whose enthusiasm for rowing began as an undergraduate (he was captain of the 1922 crew) and has never waned. Mrs. McCurdy came with him from Seattle on September 23 to christen a new shell for use by the M.I.T. women's crew.

noon visit to the Anthropological Museum in Mexico City.

Boarding buses on March 16, Fiesta registrants will visit Cuernavaca and proceed to overnight accommodations in Taxco. A banquet Tuesday night in Taxco will precede the trip back to Mexico City on March 18. The cost, including air fare from New York, is estimated at $750, and further information is available from Joseph J. Martori, director of class and course programs for the Alumni Association, Room 10-110, M.I.T.

Fostering the Arts

Free admission for M.I.T. students to the Boston Museum of Fine Arts — "a good idea that's been kicking around for years," says Nick B. Adams, '81, vice-president of the Undergraduate Association — has finally come to pass. The Council on the Arts has assembled a $7,500 fund for what is called a "college discount membership," and M.I.T. students with appropriate identification will be the beneficiaries.

$12 Million for Technology Adaptation

M.I.T.'s cooperation with Cairo University will continue for three more years under a $12 million grant from the U.S. Agency for International Development to the Institute's Technology Adaptation Program.

In the first phase of the cooperation, beginning in 1976, some 14 M.I.T. and Cairo faculty members together headed as many studies in energy, public works, manufacturing, and socioeconomic development; the new grant will permit continuation and expansion of these, according to Professor Fred Moavenzadeh of the Department of Civil Engineering, director of TAP.

A Fellowship for Productivity

In a new era of emphasis on manufacturing productivity, stronger ties are needed between engineering education and the industrial world. Thinking thus, American Can Co. has launched what it hopes will be a pilot-model faculty fellowship program at M.I.T.: junior-level engineers are funded for one year of work at an American Can plant to acquire industrial experience in their fields of specialization, and they then take junior faculty posts at M.I.T.

The first such fellow is Ming-Kai Tse, who will spend the 1981-82 year at the Greenwich, Conn., headquarters of American Can Co. Then he'll return to M.I.T. as assistant professor in the Department of Mechanical Engineering, focusing his teaching and research in the Laboratory for Manufacturing and Productivity.

Professor Kent F. Hansen, associate dean of engineering, likes the fellowship program. He sees "a noticeable increase in students' desire to apply knowledge to real-world problems," and in response he wants "a cadre of junior faculty with significant experience in industry."

Meeting in the Name of Osiris?

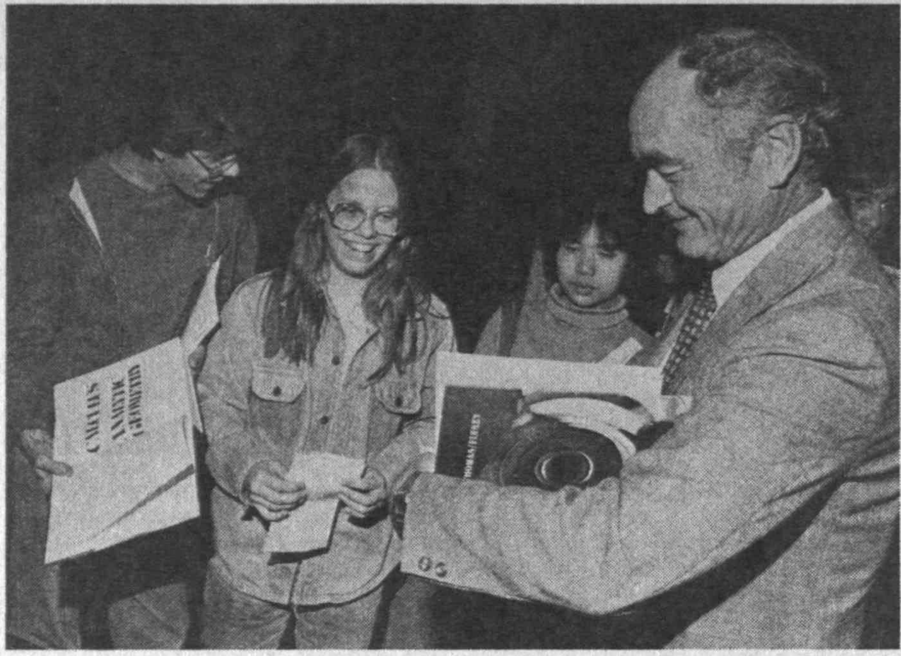
Is Osiris, the "secret" society of faculty, students, administration, and alumni which prospered in the 1930s and 1940s, coming back to life? Not as Osiris, says Peter G. Balbus, '81. But the idea of fellowship devoted to better understanding has not been lost on the present advocates of an open forum format for discussing mutual interests.

Though Priscilla Gray's lasagne may be one incentive, a bigger one is to be served: the goal of "regular, open communication between the various segments of the M.I.T. community . . . is just as appropriate now as it was in the first decades of this century," writes Stephanie Pollack, '81, editor of *The Tech*.

Sea Grant After One Decade

After ten years and the establishment of several score Sea Grant programs at colleges and universities throughout the U.S., M.I.T. "is clearly the Sea Grant leader in the ocean engineering field," says Ned A. Ostenso, national director of the Sea Grant program in the National Oceanic and Atmospheric Administration (NOAA).

Indeed, the very definition of "ocean en-



That old familiar name on the calculus book became a reality for several hundred M.I.T. undergraduates one day last fall when Professor Emeritus George B. Thomas, Jr., returned to give a special lecture. It was almost like the rock fans crowding their star for autographs, with James C. Mihori, '83, of The Tech *in the role of the papparazzi.*

gineering" is credited to M.I.T., Dr. Ostenso said at the tenth anniversary celebration for M.I.T.'s Sea Grant activities on October 23. It was Professor Alfred A.H. Keil who put forth that concept: the use of all the engineering sciences for the development of ocean resources and for studying the implications of that development.

After ten years at the Institute, the Sea Grant Program has been found by a faculty committee to be "wholly compatible with the Institute's educational objectives," and President Paul E. Gray, '54, pledged continuing commitment and support to Sea Grant activities. If the 1970s were the years of Sea Grant development, the 1980s will be "the decade of Sea Grant accomplishment," President Gray said.

Lobdell Awards to Kirchner and Montgomery, Too

Two names omitted by *Technology Review* in publishing the roster of winners of the frist Harold E. Lobdell Awards in our November/December issue (*page A15*); the awards are made by the Alumni Association's Board of Directors for "outstanding service" to a single alumni activity. The omissions:

☐ **Otto E. Kirchner, Jr.**, '49, for support of the club activities in the Pacific Northwest.

☐ **H. Dubose Montgomery, Jr.**, '71, for club and fund-raising support in the San Francisco area.

Even before the death of her husband, Norman Levinson, '33, Institute Professor in the Department of Mathematics, Mrs. Fagi Levinson was busy finding homes-away-from-home for M.I.T. undergraduates. She's continued this work with increasing vigor as chairman of the Alumni Association's Host Family Program and Student Summer Job Program, and this fall Charles Markham, '81, president of the M.I.T. Undergraduate Association, chose the first meeting of the Alumni Advisory Council to present a citation of appreciation.

AMITA: Helping Women Find Their Way in Technology

Those of us who participated in the high school visiting program (known as the AMITA Project) last year were uniformly enthusiastic about the opportunity to meet with young women early in their high school careers. In teams of four to six people, we talked with them about careers in technology and the importance of taking mathematics and science courses to keep open options for technical careers. Sixty alumnae participated in this program (along with 22 members of the M.I.T. faculty and staff and alumnae members of the Educational Council), visiting with 1,200 students in 18 different schools. Feedback from both the schools and the speakers has been overwhelmingly favorable — the speakers all want to do it again, and school officials say that the visits were effective in offering guidance, providing role models, and establishing contacts for the high school students. So we will repeat the program this spring, trying to reach more students in more schools.

It should be noted that this program came about through the inspiration and hard work of some very dedicated alumnae, most notably Susan Kannenberg, '67, and with the support and significant time commitment of members of the M.I.T. Admissions Office. We much appreciate contributions of the Admissions Office staff (especially Marilee Jones, assistant director of admissions) in organizing and evaluating this event. In her final report of the project Ms. Jones concludes that, "This program was made possible only by the generous offer of experience and time by one of the Institute's most valuable and underutilized resources, its alumae." Let's strive for more opportunities to work co-operatively towards the goal of increasing the pool of qualified women applicants to M.I.T.

Dean's Office Changes

AMITA held several interesting programs during the fall. In September we met with Dean Shirely McBay, the new dean for student affairs who is the highest ranking woman administrator at M.I.T. We learned about the reorganization which took place last year in the Dean's Office, including the creation of a new position, "co-ordinator for women student interests," currently held by Emily Weidman. Anita Walton's position as "program co-ordinator for dining and residence programs" is also new.

Women students have frequently expressed interest in opportunities to meet women further along in their careers. Alumnae who are interested in meeting with current students may wish to contact Ms. Weidman (253-5323) or Ms. Walton (253-4051) to explore possibilities. It should be noted that McCormick Dining Hall is once again open this year. Alumnae are welcome to go there to enjoy a meal with women stu-

dents. Alumnae are also invited to stop by the Cheney Room (3-310) on Thursday afternoons from 4 to 6 p.m., when women students gather to listen to speakers, share ideas, and meet each other. Next spring Ms. Weidman would like to invite alumnae to talk about their careers. If you would like to participate in one of these sessions, please let her know.

Other AMITA programs in the fall included a meeting at the M.I.T. Historical Collections with women student leaders and a meeting at the Women's Independent Living Group (WILG) with Dorothy Weeks, '23, discussing her six decades of professional experience.

A highlight of the Independent Activities Period continues to be the seminar, "Getting the Job You Want in Industry: A Woman's Guerilla Guide to the Pin-Striped World" given by Chris Jansen, '63, and Lita Nelson, '64.

If you have information you would like to have included in this column in the future please contact Ms. Bonny Kellermann, '72, Room 5-104, M.I.T., Cambridge, MA 02139

B. Kellermann

Bonny Kellermann Takes On the Educational Council

Bonny Kellermann, '72, who has been assistant dean for student affairs since 1974, becomes director of the Educational Council on January 1. She succeeds Joseph A. Edwards, '72, who left the Institute in the summer to enter a family business.

In the Dean's Office, Ms. Kellermann has had major responsibility for freshman orientation, advising, and information activities. More recently she has also been coordinator for services to handicapped students.

As director of the Educational Council, Ms. Kellermann will work with nearly 1,400 alumni volunteers who interview and counsel high school students interested in the educational opportunities at M.I.T. Among her duties will be recruiting and training new volunteers, and in this task, she says, one of her priorities will be to increase the number of minorities and women counselors.

Ms. Kellermann studied political science at M.I.T., and she holds a master's degree in social work from the University of Chicago (1974).

Some Little Things for the President's Christmas Stocking

With Santa Claus on his way, who at M.I.T. wants what?

Attempting that answer in a tongue-in-cheek *The Tech* editorial early this month, Steven Solnick, '81 included on President Paul E. Gray's Christmas list "a little shack to keep the physicists happy" and "somebody — anybody — to pay for that new dorm!"

Members of the Corporation Development Committee who listened to President Gray at their annual meeting on November 6 know that Mr. Solnick is right on target. Here are some items from Dr. Gray's "wish list" as given to this audience of key M.I.T. supporters:

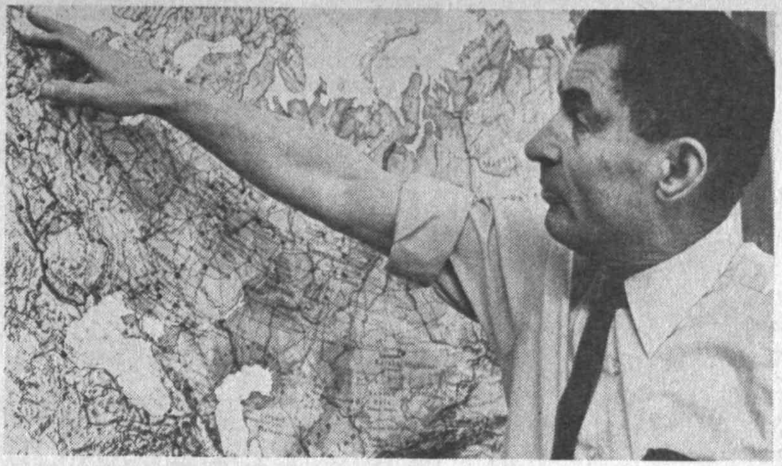
☐ Funds for faculty salaries. "How we maintain and build a faculty of the highest quality is M.I.T.'s most serious problem for the next decade," President Gray told the CDC. He emphasized the continuing need for professorships (Leadership Campaign gifts for this purpose were $40 million against a $50 million goal and an even larger need) and M.I.T.'s special problem in high-technology areas. With a national shortage of talent, it's a "boom within a recession" for these people, said Dr. Gray, and faculty positions go begging because we can't match industrial salaries.

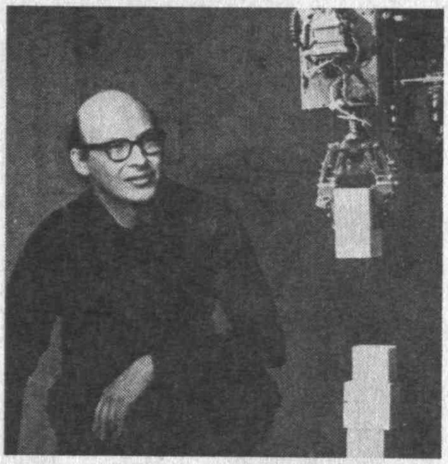
☐ Student aid funds. As numbers of college-age young people decrease during the next decade, the competition among universities for the best of them will increase. If M.I.T. is to succeed in this market it must have strong financial aid resources. Already, thinks Dr. Gray, aid offers affect graduate admissions.

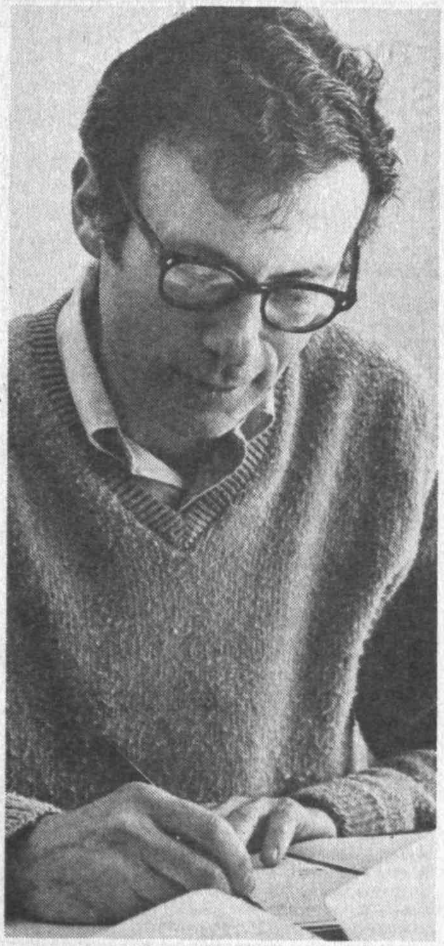
☐ Additional student housing. There is "enormous pressure" for on-campus housing, said President Gray. He thinks its availability "may affect the caliber of students we are able to attract" in the future and may also become a factor in attracting high-quality new faculty.

☐ Support for new and strengthened programs. Among these needs: new classrooms for electrical engineering and the Sloan School of Management; renovations of the chemistry laboratories in Buildings 4 and 8 and of classrooms and studios in architecture and planning; new facilities for research in very large integrated systems (VLSI) technology and the visual arts and media technology; new buildings for physics, psychology, and the cognitive sciences; and program support for the Energy Laboratory.

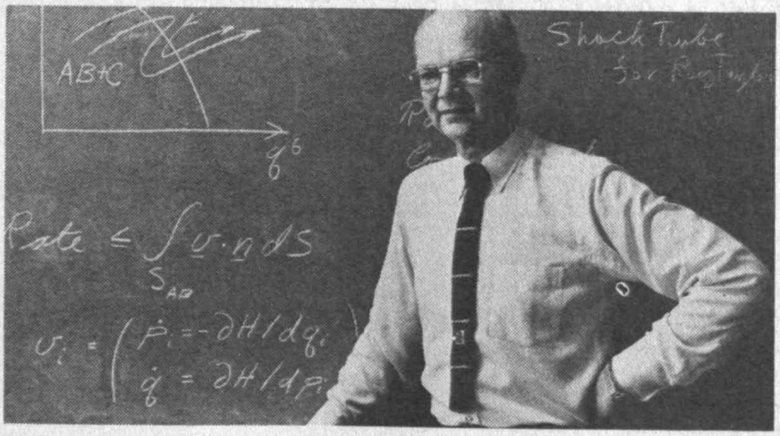
☐ Keeping up with inflation. The Institute's income is going up each year at only 80 percent of the rate of inflation, leaving an annual $1.5 million gap in on-going operations without any program growth of the kind President Gray was outlining to CDC members.







When the Leadership Campaign began nearly six years ago, M.I.T. had just over 60 endowed professorships; now it has 105, but President Paul E. Gray, '54, says maintaining faculty quality is still the Institute's "most serious problem." On these pages, a gallery of some of M.I.T.'s distinguished chairholders: (top to bottom) Professors Evsey D. Domar (economics), Gerald Holton (science, technology, and society), Marvin L. Minsky (electrical engineering and computer science), Arthur P. Mattuck (mathematics), Robert M. Fano, '41 (electrical engineering and computer science), and James C. Keck (mechanical engineering).



Puzzle Corner
Allan J. Gottlieb

How Many Friends With Birthdays?

Allan J. Gottlieb is associate professor of mathematics at York College of the City University of New York; he studied mathematics at M.I.T. (S.B. 1967) and Brandeis (A.M. 1968, Ph.D. 1973). Send problems, solutions, and comments to him at the Department of Mathematics, York College, Jamaica, N.Y. 11451.

Since this is the first issue of 1981, we are presenting another of our "yearly problems" in which you are to form numbers from the digits 1, 9, 8, and 1 and the arithmetic operators. See the "Problems" section for details and the "Solutions" section for the answer(s) to the 1980 yearly problem.

A short remark on problem backlogs is in order. I have a large supply (greater than a year's worth) of regular, speed, and chess problems; but there is a shortage of bridge problems.

Problems

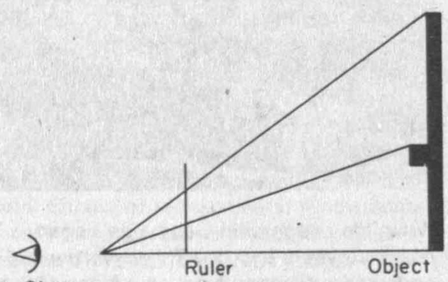
Y 1981 Form as many as possible of the integers from 1 to 100 using the digits 1, 9, 8, and 1 exactly once each and the operators +, −, * (multiply), / (divide), and ** (exponentiation). We desire solutions containing the minimum number of operators; and, for a given number of operators, solutions using the digits in the order 1, 9, 8, and 1 are preferred.

JAN 1 Phillip Feuerwerger wonders what is the probability of picking up a bridge hand containing no suit with exactly three cards.

JAN 2 James Boetler has been unable to find a set of five distinct positive integers such that the sum of each pair is a perfect square. Does such a set exist?

JAN 3 Raymond Cowen has a balancing scale and 15 billiard balls. He knows that 14 of the balls are identical in weight, but the fifteenth is either heavier or lighter. What is the minimum number of balancings needed to isolate the "odd" ball?

JAN 4 Our next problem is from Frank Rubin, who writes:



One good way to estimate the height of an object is to take a known height, sight along a ruler until the known object subtends an easy length to work with, and then take the proportional height subtended by the unknown object. If the ruler is parallel to both objects, the results will be exact. Recently I attempted to measure the height of a bridge this way. I had a friend who was exactly six feet tall stand next to the bridge tower. I held the ruler so that he appeared to be one inch tall; the height of the roadway then ap-

peared to be four inches and that of the supporting tower ten inches. Hence I estimated that the roadway was 24 feet above ground and that the tower was 60 feet high. Later I found that the roadway was actually 26 feet above the ground. Clearly this was because I did not hold the ruler precisely vertical. What, then, was the correct height of the tower?

JAN 5 Our last regular problem, from Ernest Steele, is an extension of the famous birthday problem:

I have occasionally asked an acquaintance to estimate the number of people that would give a 50-percent probability of having two coincident birthdays in one year. My friends are always greatly surprised when I tell them that only 23 are needed. This is determined, of course, by

$1 - [(364)(363)(362) \ldots (366 - n)]/365^{(n-1)}$.

But then I became interested in the problem of the minimum number of people needed to give at least a 50-percent probability that there would be three coincident birthdays in the year.

Speed Department

JAN SD 1 Our first speed problem is from William Katz:

Three equal applicants for promotion are led into a room, blindfolded, seated at a table, and told, "While we were blindfolding you, we put a dark spot on none, one, two, or all three of your heads. When we remove the blindfolds, if you see at least one spot, put your hands on the table. If you *know* what you have, stand up. But if you cannot explain, you lose your chance of promotion. All three were marked. Of course all put their hands on the table when able to see. Finally, B arose. How did he *know*?

JAN SD 2 Blaine Rhoades has a quickie about a quick car:

A car is driven once around a one-mile track at exactly 30 mph. How fast must the second lap be driven in order to average 60 mph for the full two-mile course?

Solutions

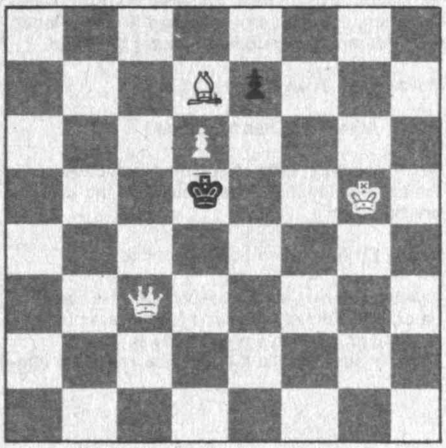
Y1980 The problem is the same as Y1981, preceding, except that the numbers 1, 9, 8, and 0 are to be used. As expected, the zero made this a very difficult year. Al Weiss made the best of a bad situation and used leading zeros to reduce the number of operations needed for 11 of the 29 solutions he found. His response follows; he notes that because he was not sure numbers such as "01" were acceptable, he provided alternate solutions in the cases where his best solutions contained such a number.

1:	1**980	11:	91 − 80
2:	018/9	12:	108/9
	1 + 98**0	16:	08 + 9 − 1
4:	8/(1 + 9**0)		0 + 8 + 9 − 1
5:	90/18	17:	18 − 9**0
6:	8 − 1 − 9**0	18:	19 − 8**0
7:	8 + 9 − 10	19:	19 + 8*0
8:	19*0 + 8	20:	180/9
9:	90 − 81	27:	018 + 9
10:	1**80 + 9		19 + 8 + 0

61:	80 − 19	82:	1*90 − 8
62:	8*9 − 10	83:	091 − 8
63:	(08 − 1)*9)		0 + 91 − 8
	(0 + 8 − 1)*9	88:	98 − 10
64:	(09 − 1)*8	89:	01*89
	(0 + 9 − 1)*8		1*9 + 80
70:	80 − 1 − 9	90:	810/9
71:	1*80 − 9	91:	0*8 + 91
72:	90 − 18	92:	8**0 + 91
73:	01 + 8*9	97:	098 − 1
	1 + 9*8 + 0		0 + 98 − 1
79:	89 − 10	98:	01*98
80:	1**9*80		1*98 + 0
81:	1**9 + 80	99:	19 + 80

Also solved by Jerry Grossman, Winslow Hartford, and Harry Hazard.

A/S 1 The proposer writes that the problem was published incorrectly, with the White King on KR5 instead of KN5. The correct diagram is published below; White is to mate in two; and the problem is now reopened.



A/S 2 Consider a set of N distinct integers, the sum of any K of which is prime. What is the maximum possible value of N for K = 2, 3, 4, and 5?

David Freeman obtained two general results: For K even, the maximum value for N is K. For K prime, $N \leq (k - 1)^2$. When applied to the cases asked for in this problem, these results yield for 2, 3, 4, and 5:

$K = 2, N = 2$.
$K = 3, N \leq 4$ and (5, 7, 11, 25) works
$K = 4, N = 4$
$K = 5, N \leq 16$.

For this last case a special argument shows that $N \leq 8$. Since (19, 49, 79, 121, 151) satisfies the conditions, the maximum N is 6, 7, or 8. Mr. Freeman's analyses are available from the editor.

Matthew Fountain has found that, for K odd, the maximum $N \geq K + 1$.

A/S 3 Given four distinct points that lie on (the boundary of) a square, construct the square. Under what conditions is the square uniquely determined?

The following response is from Norman Wickstrand:

By a rare coincidence of events I happened to be looking in Court's *College Geometry* soon after reading "Puzzle Corner," and I found there essentially the same problem. It appears that there are an infinite number of solutions for one unique combination of points. It seems to me that there will be six solutions for all other combinations of points. At least as yet I fail to see how there can be less than six squares. It seems to me that this must have been a very difficult undergraduate challenge.

Responses were also received from Harold Siegel, Elliott Roberts, Harry Zaremba, Emmet Duffy, Naomi Markovitz, and Matthew Fountain.

A/S 4 Find all possible solutions to this cryptarithmetic addition problem:

```
THREE
  TWO
  TWO
-----
SEVEN
```

The following solution is from W. Smith: There are two solutions:

```
29600
  254
  254
-----
30108
```

E = 0, V = 1, T = 2, S = 3, O = 4, W = 5, R = 6, N = 8, and H = 9.

```
79100
  752
  752
-----
80604
```

E = 0, R = 1, O = 2, N = 4, W = 5, V = 6, T = 7, S = 8, and H = 9.
Comment: With nine different letters, base-nine addition would be natural for the problem. I could find no solutions in base-nine arithmetic, however. I did not pursue bases higher than ten. Explanation: I attacked the problem by showing that (i) H must be 8 or 9, and of course S = T + 1; (ii) E must be 0 or 1; and (iii) W must be 0 or 5. Then I examined the cases: (1) H = 8, E = 0, W = 5; (2) H = 9, E = 1, W = 0; (3) H = 9, E = 1, W = 5; and (4) H = 9, E = 0, W = 5. Only case (4) bore fruit. The key to the reasoning is getting insight into what each carry is from one column to the next.

Also solved by Harry Zaremba, Naomi Markovitz, David Freeman, Winthrop Leeds, Matthew Fountain, Gregory Ruffa, Avi Ornstein, Kelly Woods, Frank Carbin, Winslow Hartford, Doug Szper, and the proposer, Theodore Goodman.

A/S 5 Solve for x:
$(3 - \log_a x)/(2\log_a x) + \log_x d = \log_x b + 2\log_x c$.
Express your answer without any parentheses or numerals, using only *one* algebraic operation (addition, multiplication, exponentiation, etc.). You may use that operation as often as you like.

The key is to remember that the log base a of b is the reciprocal of the log base b of a. Then it is easy to solve for x and get

$$x = \frac{a^3 d^2}{b^2 c^4}$$

Written with just division, this becomes:

$$\frac{\frac{\frac{a/b}{c/a}}{\frac{c/d}{d/c}}}{\frac{b}{a/c}}$$

Solutions received from Frank Carbin, Harry Zaremba, Matthew Fountain, Norman Wickstrand, W. Smith, Doug Szper, Winslow Hartford, David Freeman, Everett Leroy, Richard Kruger, Robert Schmidt, and the proposer, Draper Kaufman.

Better Late Than Never

M/A 1 Allen Keith has responded.

M/A 2 Gregory Ruffa solved the N = 8 case under the assumption that at each stage all the squares are occupied.

M/A 4 Ernest Massa has responded.

M/A 5 I. Iverson kindly resubmitted his negative proof, and Emmet Duffy and Harry Zaremba also responded. Iverson's proof follows:
There is such a solid if θ and ϕ as roots are considered as integers, with θ being the Golden Number (0.618034) and ϕ being $\theta + 1$. The dimensions of this solid are θ, 1, and ϕ. Then the face diagonals are $\sqrt{\theta^2 + 1}$, $\sqrt{3}$, and $\sqrt{\phi + 2}$. The space diagonal is 2. But neither θ nor ϕ are integers nor can they be reduced to simple fractions, but since they can represent the desired rectilinear solid, then there cannot be found integers which will do so. The basis of this (negative) proof is that, if such conditions exist for the Golden Number, then it cannot exist for integers. If this should exist for π or for e, the proof would be the same.

J/J 2 Roy Sinclair has responded.

J/J 3 Roy Sinclair, Robert Schmidt, Burton Karpay, Gordon Cochrane, and Marlon Weiss have responded.

J/J 5 Burton Karpay, Robert Schmidt, and Gerald Conrad have responded.

NS 15 William Butler submitted an article of Martin Gardner's on this problem. Apparently cyclic solutions (where one player remains stationary and the others sequence along a closed path) are known up to 24 players, and noncyclic solutions can always be found. Mr. Butler's report can be obtained from the editor.

Proposers' Solutions to Speed Problems

SD 1 B says to himself, "I see a spot on A, and C has his hands on the table. If I do not have a spot, A would stand up, seeing me with no spot and C indicating he sees one. Therefore we all have the same problem, and I have a spot."

SD 2 It's not possible.

The Power of Microelectronics

by John S. Mayo

In microelectronics, with its profound impact on science and technology, the new-age adage "small is beautiful" is especially apt.

SOME 30 years ago, Bell Telephone Laboratories demonstrated a new device called the transistor. The *New York Herald Tribune* observed at the time that "the device is still in the laboratory stage, but engineers believe it will cause a minor revolution in the electronics industry." In fact, the transistor triggered an electronics revolution around the world that promises to surpass the Industrial Revolution in its impact on human affairs.

The driving force behind this modern revolution is technologies that permit ever-greater increases in the complexity of integrated circuitry fabricated on a single semiconductor crystal. Complex circuits can be built inexpensively and reliably by putting thousands of minute circuit elements on a single chip of silicon along with the interconnecting "wiring" required to complete the circuit. An interconnecting "wire" on a silicon chip costs about one-hundredth as much as a "wire" on a conventional circuit board.

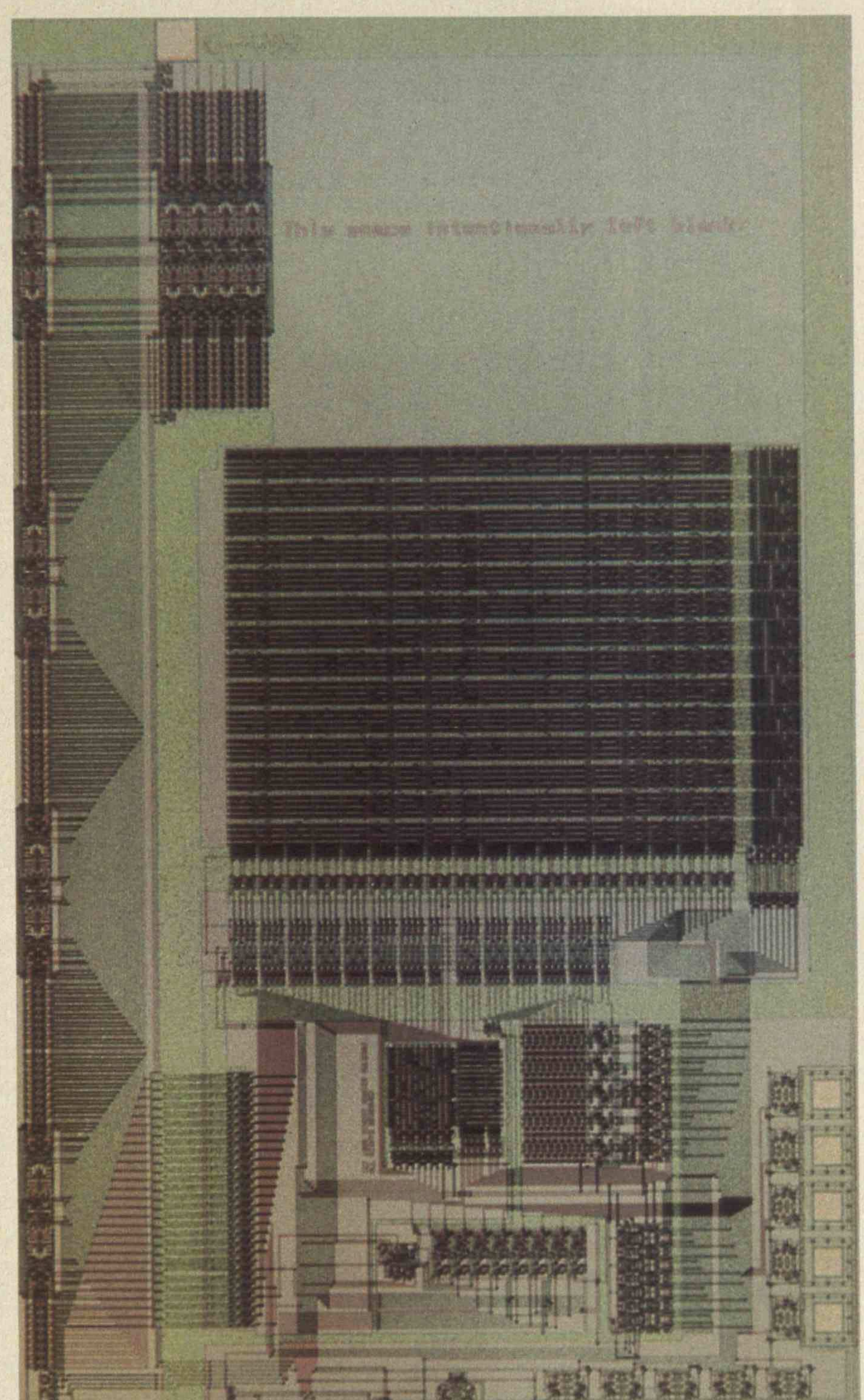
Every year since 1960, when the integrated circuit industry began, the number of components per chip of silicon has about doubled. This phenomenal rate of progress has brought us to the era of "very large scale integrated" (VLSI) circuits. Today, over 150,000 components can be fabricated and interconnected on a single silicon chip about one-tenth the size of a postage stamp, and the number of components per chip can be expected to grow dramatically for at least another 10 to 15 years.

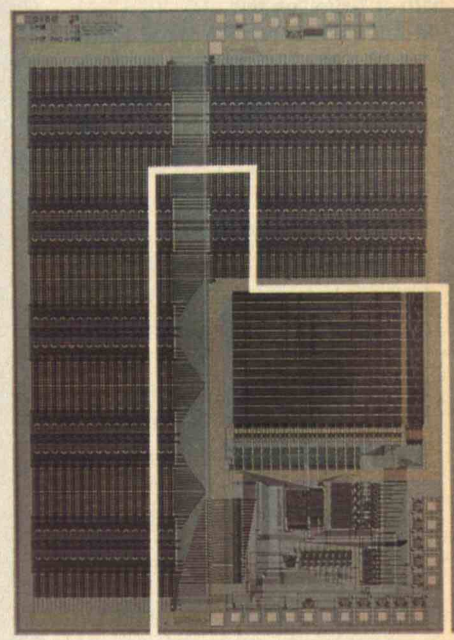
Basic research was the spawning ground of this revolution. The dedicated efforts of pioneering scientists had far-reaching repercussions, opening up new fields in science and technology, paving the way for follow-up innovations, and influencing society for generations to come. Solid-state electronics already has made enormous contributions to allied fields such as computer science and telecommunications and to others as diverse as medicine and space exploration.

With the advent of VLSI circuits, even the development of electronics technology itself depends strongly on computers and test instruments that use integrated circuits. A primary example is computer-aided design (CAD). In the last five years, integrated circuits have become so complex that without the advanced analysis and extensive simulation techniques available through CAD, it would be virtually impossible to design VLSI chips. But with CAD, even complex circuits can be designed in a few months with no real increase in labor. The integrated-circuit industry today is essentially pulling itself up by its bootstraps, relying heavily on systems built with the industry's most advanced products.

Where Less Is More

The significant attributes of a microelectronic circuit stem directly from its small size. First and foremost, extensive miniaturization has made possible low-cost electronics. The cost of a high-quality digital logic gate — a circuit that performs the electronic

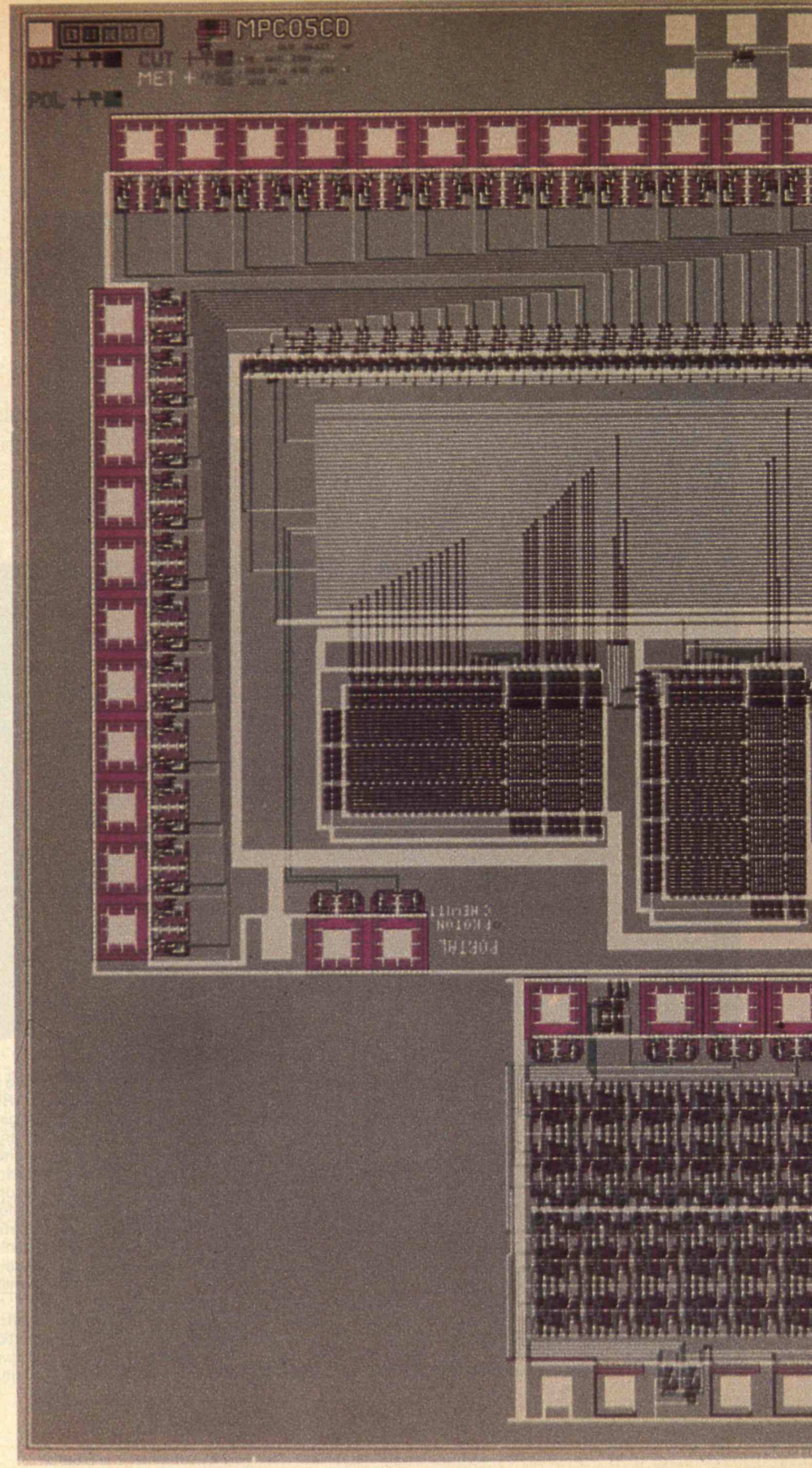


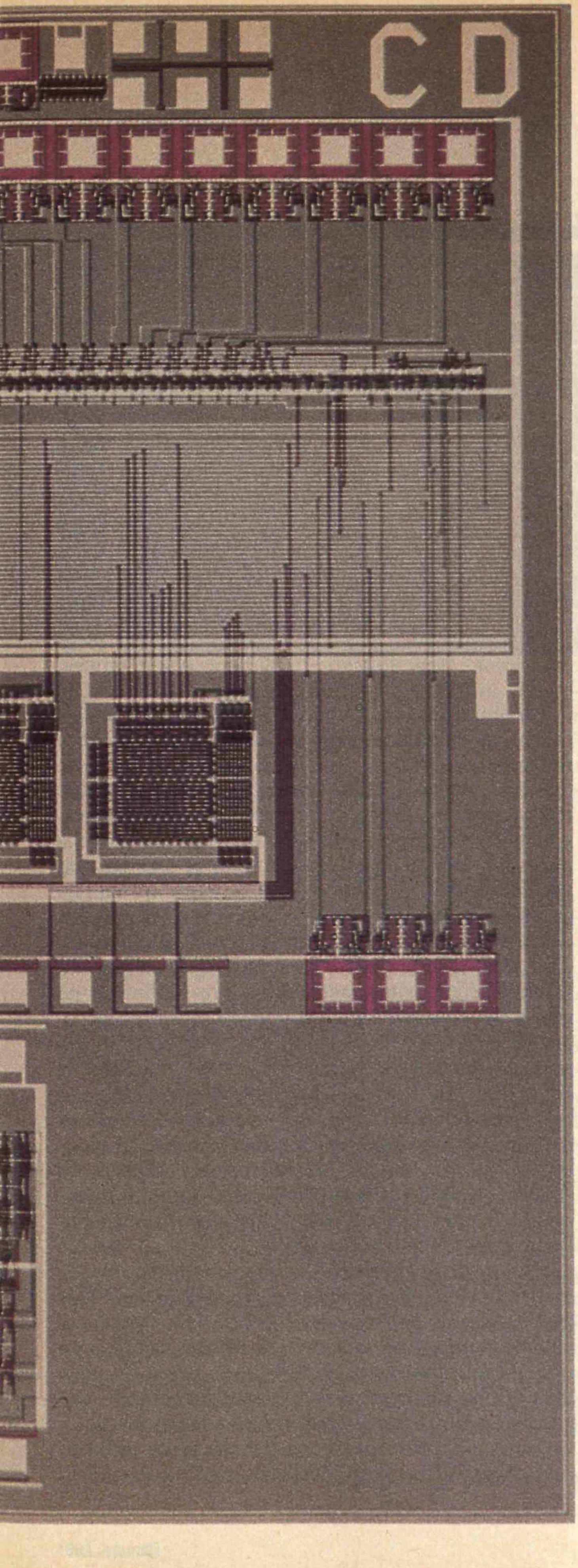


Above: This VLSI chip designed by Ronald R. Rivest, associate professor of electrical engineering and computer science at M.I.T., is an encryption device capable of storing eight numbers, each up to 512 bits (160 decimal digits) long. The chip contains an algorithm that encodes messages by performing complicated arithmetic operations on these huge numbers. An identical chip decodes the message at the receiving end. The actual size of the chip is 8 millimeters by 5.5 millimeters.

Left: This is a further enlargement of the portion enclosed in white on the photograph above and is itself an encryption circuit with a smaller capacity.

This VLSI chip enables one computer to communicate simultaneously with other computers. The chip design was begun one year ago at M.I.T. by graduate student Phyllis Koton as a project for a VLSI course and later as an independent project with Professor Carl E. Hewitt of the Electrical Engineering and Computer Science Department. The portion of the circuit at the bottom serves as a store for data and was designed separately by Paul Ries, formerly an M.I.T. graduate student and now at Intel Corp. A typical conducting path or "wire" on this VLSI circuit is about four microns wide. Industry is presently able to achieve dimensions of about one micron.





equivalent of logical functions such as "and," "or," and "not" and serves as the basic building block of digital systems — was several dollars only 15 years ago. Today a quality logic gate costs a few tenths of a cent, and the cost is still falling.

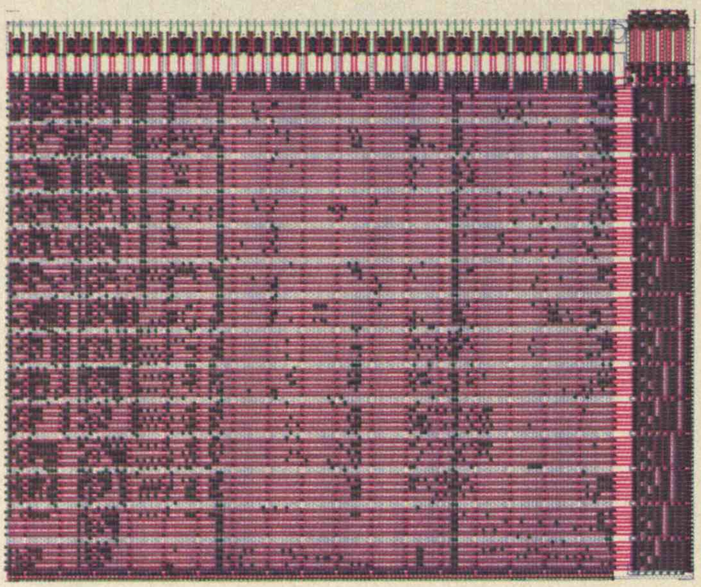
In some applications ranging from pocket calculators to aircraft guidance systems, smallness is important for its own sake, but many other applications can also benefit from space savings. For example, the digital memory of the first telephone electronic switching system used magnetic devices and required a lineup of equipment frames 104 feet along the floor. With 16-kilobit (16-thousand-bit) memory chips in use today, the same amount of memory occupies a fraction of one equipment frame, and the size is being further reduced with a design using 65-kilobit VLSI memory chips.

Small size also saves energy. As more and more circuit elements are packed onto a silicon chip, less power is consumed per element. These circuits require smaller power supplies, and therefore the systems built with them are more portable. Even in very large data-processing and telecommunications centers, the use of VLSI can result in significant power reductions and therefore help to control overall energy consumption.

Miniaturization has also stimulated a wide range of developments for dealing with the micron (one-millionth of a meter) and even submicron dimensions that VLSI involves. For example, VLSI lithographic and analytic tools and instrumentation are used in related industries, and x-ray analysis machines and electron microscopes, common in the VLSI industry, are increasingly applied to other sciences and industries concerned with microscopic entities. The outlook for the future is continued rapid progress in these areas, with especially important implications for basic science and technology, computer science, data processing, and communications.

Shorter Routes to Knowledge

Integrated-circuit technology is making computation increasingly inexpensive and accessible, with major impact on the basic sciences. Computers have made possible the use of complex, previously unmanageable information, thus augmenting and accelerating scientific processes. In turn, the use of computers for research and development in all fields



This felt-tip-pen drawing of a VLSI circuit was generated by a Hewlett-Packard four-color pen plotter. The plotter, used in M.I.T. student VLSI computer-aided design projects, produces a circuit diagram based on information in a computer. A set of masks is produced from the information used to make the plot — one mask for each color. Each mask corresponds to a certain type of circuit element. For example, one mask might indicate areas for metal conductors. In lithographic fabrication of integrated circuits, light beams are used to project the masks' patterns onto a silicon wafer coated with light-sensitive resist. Newer techniques call for x-rays or electron beams, which can achieve finer lines.

stimulates ideas that advance computer science and engineering.

During 1979, the use of computers helped to uncover fundamental knowledge about the history of the universe. Specifically, digital computation was used to detect and classify faint objects in the sky automatically. Enormous amounts of data were collected through a terrestrial telescope and fed into computers that enhanced and analyzed the images. With VLSI, such major computational resources will be increasingly available to large numbers of researchers, surely enhancing the quest for new knowledge.

VLSI is also putting new tools into the hands of researchers. For the study of deep-sky objects, a VLSI imaging chip (called a charge-coupled device) containing arrays of light-sensitive elements organized to simplify computerized analysis was used to gather data. Such imaging devices make possible powerful television cameras and other image-sensing systems often required in basic research. VLSI circuits, especially in the form of microcomputers, greatly augment the capabilities of laboratory equipment. Precision control, error-free data recording, and real-time data manipulation and display are just a few of the powerful features economically available as a result of advances in solid-state electronics. We will soon have a wide range of integrated instrumentation systems in which many types of diagnostic functions will be accommodated simultaneously under computer control.

The implications of microelectronics for basic science and technology are strongly coupled to the fundamental symbiosis between solid-state technology and science. Basic science contributes to the technology of fabricating new microstructures, which in turn gives rise to new tools that support the quest for knowledge. For example, as smaller and smaller circuit dimensions are sought, it will be necessary to explore the ultimate limit of how much complexity can be incorporated on a silicon chip. The solid-state industry has moved from an era when discrete components a square millimeter in size were standard to today's VLSI chips that incorporate 5,000 or more components onto a similar area. Some discrete high-frequency components have been built with submicron dimensions, and there are indications that dimensions in the tens of nanometers (one-billionth of a meter) are technologically feasible. Such dimensions are 100 times smaller (10,000 times smaller in area) than the current chips and may lead to packing more than 1 billion components on each chip.

How will we get there? Basic science will provide many answers. In lithography, optical systems that project circuit patterns onto silicon wafers are capable of producing lines with widths of about one micron, and lithographic techniques based on electron beams, ion beams, and x-rays can achieve even narrower dimensions. Each approach has both advantages and problems. For example, electron-beam lithography offers high resolution and depth of field

but is limited by the high cost of such machines. Continued progress in materials science and chemistry will help overcome these problems with the fabrication of so-called "nanostructures," generating new knowledge for application to microfabrication techniques.

Once we know the fundamental and practical limits of VLSI, we will have learned a great deal about basic science that is sure to have a powerful impact on technology. Studies of the practical limits of low-voltage and low-current circuits and their interaction with sources of noise will provide much vital information to electronics engineers. Investigations of lithographic techniques will greatly enhance capabilities for generating and controlling light, x-rays, and electronic beams and for influencing their interactions with matter. The extension of technological capability in dealing with microscopic features will have a major effect on creating minuscule patterns and controlling chemical processes on such minute entities. Indeed, there are signs that we may eventually be able to structure matter itself by building new materials and structures a few atoms at a time.

Cutting the Cost of Computing

Science education will have to change to meet the demands of the microelectronics revolution; solid-state electronics has already led to dramatic changes in the content of technical courses. This has been especially profound in the field of electrical engineering, the major wellspring of the closely allied and fast-growing field of computer science. Within electrical engineering itself, a survey of several colleges shows that about half the junior-year courses and most senior-year courses are new or substantially altered as a result of the solid-state revolution's impact on engineering concepts. A large part of this change reflects the growth of digital technology, which is rapidly displacing earlier analog techniques. Hence, a wide range of courses in the design and use of digital systems has emerged. The swift evolution in the content of engineering and computer-science courses will continue as VLSI further extends the penetration of digital technology into the engineering world and increases the availability of computing resources, the very tools of education.

The low cost and small size of integrated circuits has had a revolutionary impact on computer science and data processing: the cost of using large computing machines to process data has decreased by a factor of about 1,000 over the last 20 years. Medium-sized machines or minicomputers can often further reduce costs by a factor of 5. And now, many jobs can be handled by microcomputers on single chips of silicon, reducing costs for these jobs by another factor of 100. These microcomputers, available today for as little as a few dollars each, can do many of the computing jobs that just 20 years ago required machines costing several hundred thousand dollars.

The advent of microelectronics has made the advantages of computers available over a much wider range of applications. When large, expensive machines were the only computers available, the jobs had to be brought to the computer, and large computation centers had to be kept fully used to be economical. Today, with rapidly declining machine sizes and computing costs, computers are increasingly being brought to the job. Nor does every computer have to be used all the time to be economical.

With computing resources widely available, computer programmers and software designers are in high demand — there simply is not enough talent to program all the computers that can now be operated economically. Also, the economic impact of the software itself is becoming increasingly important. A microcomputer may cost only a few dollars and be manufactured by the millions, while just one program for the microcomputer may cost tens or even hundreds of thousands of dollars.

To put it bluntly, computer science has not yet provided enough basic knowledge and tools to improve programming productivity to make full use of microelectronic technology. Much of the solution to this problem may be found in the technology of VLSI itself. Because it is becoming increasingly possible to put portions of the software right on the chip, software specialists — programmers, systems analysts, and even users — can now work closely with hardware experts in designing microcomputers.

Future Connections

VLSI will make possible systems even more complex in hardware and simpler in software, opening a new area of software science — distributed software systems, wherein a whole family of computers of many sizes operates under centralized software control.

Are VLSI Circuits Too Hard to Design?

by Arthur L. Robinson

SEMICONDUCTOR experts confidently predict that microcircuits containing millions of transistors can be manufactured in the next decade. There is only one problem. Organizing a million transistors on a silicon chip into a useful circuit is a formidable undertaking, and the tools for designing such a complex device do not yet exist. Faster and less expensive ways to design microcircuits will be necessary if the industry is to continue to expand at its projected growth rate.

Microprocessors are the most intricate integrated circuits (ICs) now being made. It already takes a team of a half-dozen design engineers a year or two to develop a state-of-the-art microprocessor. The next generation of ICs, called VLSI (very large scale integration), is where the design problem becomes acute. With existing computer aids, one person in a year's time can design about a thousand logic gates in an IC at a cost of approximately \$100 per gate. By 1990, 1 million gates on a chip may be possible, but even if the cost per gate decreased to \$10, the entire chip would still cost \$10 million to design.

A look at IC design practice helps explain why the process is so lengthy. A microprocessor consists of several subunits that perform various functions. A logic designer builds up these subunits according to the principles of computer design. Then, a circuit designer converts the logic design into electronic circuits, and a layout designer works out the placement of logic gates on the silicon chip that corresponds to the desired circuits. Finally, a draftsperson draws an accurate circuit layout for use in the microfabrication process. Moreover, the design procedure may go through a series of loops in which corrections and modifications are made. The process quickly becomes time consuming and expensive.

What can be done to manage the complexity of VLSI microcircuits? One solution is to make logic circuits more geometrically regular. Two methods are already in use.

The first is the "programmable logic array" (PLA), consisting of two kinds of logic gates arrayed in a very specific manner, one made entirely of gates of the first type and the other made of the second type. The logic function of the array is determined by which devices are interconnected within the two arrays. Because the gates are laid out in a regular pattern, the main design problem is to decide which gates to connect. In addition to being easier to design, PLAs offer some flexibility: their function can be altered simply by changing the interconnections. Thus, major changes can be made in a microprocessor without a completely new design. The penalty for the simpler design process is that the PLA takes up more space than other logic circuit designs. Since the cost of fabricating an IC is determined almost entirely by its area, there is considerable premium on keeping it small. Nevertheless, PLAs are now quite common in microprocessors.

In the second approach, "master slices" or gate arrays provide a way to manufacture custom ICs while reducing design time, perhaps by as much as a factor of six. As manufactured at IBM, which first used the concept successfully in designing digital circuits for its newest computers, master slices consist of columns of identical "cells" comprising several interconnected transistors. The columns are separated by evaporated metal-filled channels that serve as "wires." All master slices are identical until the last stages of the manufacturing process, when the cells are connected to the "wires." The particular pattern of interconnections determines what kind of logic circuit the master slice becomes. At IBM, the process is largely automated: the designer indicates to the computer what function the circuit is to perform, and the computer determines the pattern of interconnections. Master slices are more versatile than PLAs but they also use space on the silicon chip inefficiently.

Computers Aid VLSI Design

Another way to simplify IC design is to divide a microcircuit into functional subunits — an idea borrowed from computer programming. Paul Penfield of M.I.T. points out that large programs may contain a million or more instructions and thus are comparable in complexity to the projected VLSI circuits. Ways of dealing with complexity in computer programs, if not directly applicable to IC design, provide a starting point for attacking the problem. Structured programming, for ex-

Computer science is only now beginning to contribute knowledge to the difficult task of designing such systems. VLSI, by increasing the demands on computer science, is stimulating the generation and flow of knowledge needed to make the design of distributed software systems into a science. However, even simple software designs remain more of an art than a science.

The impact of microelectronics on communications is nearly as profound as its impact on data processing. Each new milestone in chip complexity reduces the cost of electronic equipment, bringing a wider range of sophisticated services within economic reach of more people. For example, microelectronics is driving the expansion of "stored-program control" in the nationwide telecommunications network. In stored-program control, a system such as a telephone switcher includes a digital pro-

ample, is a technique that divides a complex program into modules that can be written by separate groups of programmers. A similar method could be applied to microcircuit design.

IC designers have had access to computer-aided design (CAD) tools for several years, but it is generally agreed that for computers to make significant contributions to the design of complex VLSI circuits, some radical thinking will be required. A principal objective of CAD is to give the computer a more central role in the details of design and testing of ICs, allowing humans to concentrate on more creative aspects of design. Another analogy with computer programming shows what CAD could do.

Compilers are computer programs that translate programs written in "high-level" languages such as Fortran or Basic into a sequence of binary numbers that the computer interprets as instructions. An analogous program could transform a high-level description of an IC written by a designer into a detailed layout of every transistor and wire on a chip. Quite complicated ICs have already been designed this way.

A program called "Bristle Blocks," designed by California Institute of Technology graduate student David Johanssen, aids in the design of a particular type of microprocessor. The microprocessor is partitioned into cells, and the designer gives a high-level description — perhaps taking only two or three typewritten pages — of the functions the cells are to perform. The program then generates the circuitry within each cell, locates the points where the cell must connect with other cells, and arranges the cells so that the proper connection points meet. Bristle Blocks refers to the appearance of the rectangular cells covered with interconnections.

So far, says Johanssen, the Caltech group has not designed an entire microprocessor using Bristle Blocks, but it is getting close. Once the functional descriptions of the cells are in hand, the program takes only five to ten minutes to come up with a chip layout. While Bristle Blocks by no means solves the entire design problem, the program does accomplish about three human-years of work in a few minutes, and it would be hard to see how the semiconductor industry could be unreceptive to such a tool.

Artificial Intelligence to the Rescue

A project at M.I.T. under the direction of Gerald Sussman takes the process a step further. Sussman does artificial intelligence research and he wants to understand how humans go about designing things from bridges to ICs. Sussman and his co-workers have chosen VLSI circuits as the type of system they would like to write a program to design. Although their work is far from complete, the group has already constructed a program with which they designed a microprocessor with some 50,000 transistors. Sussman predicts that design tools based on artificial intelligence concepts should eventually permit ICs of every kind except state-of-the-art chips to be designed from a high-level description of the desired functions written by software engineers — programmers — not circuit designers.

Most of the activity in figuring out faster ways to design ICs has been directed toward making it easier to build conventional logic circuits. But logic circuit concepts were formed when electrical switches — vacuum tubes — were expensive and connecting wires were of negligible cost. The idea was to design the logic so that there were as few switches as possible. Today, however, the cost of a transistor — the switches in digital ICs — or a "wire" on an IC is determined only by the area it occupies, and "wires" already account for as much as half the area of a chip. In VLSI circuits, the imbalance will get worse. Hence, a major focus of VLSI design should be on minimizing "wires," not transistors. Engineers should focus on the interconnections in VLSI design, but instead, they work on logic diagrams while the computer does the wiring in master slice design. A complete reversal of priorities is needed.

Satisfactory tools for designing the wondrous chips of the next decade do not yet exist. Until they do, VLSI will be unable to live up to its promise of lowering the cost of digital computation, thereby bringing the benefits of automation and intelligence to myriad applications.

Arthur L. Robinson is a staff writer for Science *magazine from which this article was adapted.*

cessor that can be programmed to control the system. Thus, the system's features can be readily changed by modifying the control program. Thousands of these stored-program-controlled systems are now in use in the telephone network, the largest distributed processing network in the world.

Stored-program control has greatly enhanced the quality of telecommunications services. Already a business customer can enjoy private network services and exercise a great degree of control over individual service features. VLSI also makes it practical for private branch exchanges (PBXs) to provide stored-program control directly on a customer's premises. Smaller businesses benefit from the stored-program capabilities of such electronic PBXs through sophisticated key telephone systems (*see "Technology and Change in Modern Communications" by Ithiel de Sola Pool, Nov./Dec., p. 64*).

Machines that recognize your voice, call you by name, and respond to spoken command may become commonplace through the use of VLSI.

Nor is the power of stored-program control in telecommunications confined to private network services. Largely through software changes, the network's electronic processors will be programmed to provide a host of new, innovative telephone services to the public. In fact, many advanced public telecommunications services are already either available or being demonstrated. Electronic switchers now make it possible to forward calls automatically, to reach frequently called numbers through abbreviated dialing codes, to notify users of other incoming calls, and to conduct three-way conference calls. Future services might include the screening of incoming calls and automatic credit-card calling.

Other communications concepts are on the horizon. Advanced Mobile Telephone Service can provide service to large numbers of people in vehicles and is working well on a trial basis in Chicago. And the VIEWTRON system, on trial in Coral Gables, Fla., enables one to display on a television screen some 15,000 "frames" of information — some interactive — transmitted via telephone lines from a data bank.

The new VLSI technology will make possible a concept that has been largely a fantasy until now — machines that speak, listen, and act upon command. This long-sought communication between human and machine offers great potential in communications, education, and transaction and reservation systems, as well as a vast array of other information services.

Although machines that generate speech — such as those that report changed telephone numbers — have been in use for some time, a machine that can recognize your voice, call you by name, and respond to your spoken command is more difficult to devise. Such machines exist today mainly in research laboratories, and their widespread use will depend largely on substantial reductions in the cost of the highly complex electronics and large memories needed to achieve useful vocabularies and swift responses. But advances in VLSI are stimulating extensive research and development in this field, and VLSI will provide the needed cost reductions.

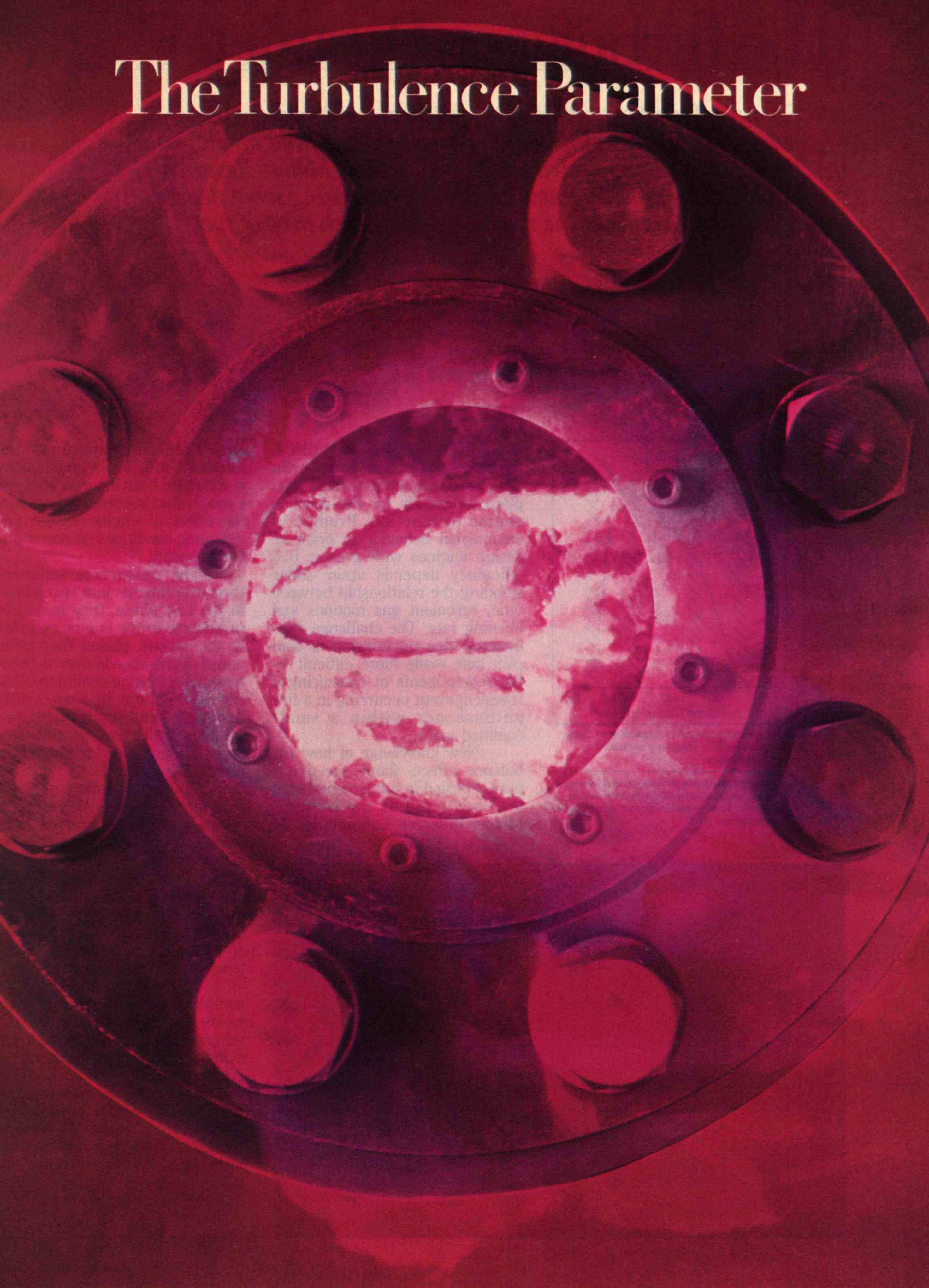
The decreasing cost of digital circuits is creating other opportunities in communications. For example, the echoes on telephone circuits carried via satellites have long been a problem. Although a method of canceling out these echoes was invented some time ago, each canceler required costly equipment about the size of a home refrigerator at the ends of each telephone circuit. Now, that entire circuit has been placed on a single chip of silicon, and it has become practical to deploy echo cancelers not only on satellite circuits but on long terrestrial circuits as well.

Microelectronics — and VLSI in particular — is a powerful technology offering tremendous advantages. VLSI is a rich source of ideas and tools for a wide range of industries, and its impacts on the basic sciences, data processing, and telecommunications are affecting numerous other fields. For example, VLSI-based technology now aids physicians with increasing amounts of computer support and a vast array of complex, "smart," and rapid diagnostic instruments. Future space exploration — and exploitation — will depend largely on VLSI-based control and communications equipment. Energy development and conservation will benefit from "smart" yet economical instruments and controls. Microprocessors will increasingly control automotive operations such as carburetion and timing to improve fuel economy and reduce emissions. More and more chemical processes will be monitored and controlled by microcomputers to maintain product quality, reduce waste, and minimize air and water pollution.

Our society has eagerly accepted the products of the microelectronics revolution so far. The impetus of this revolution will continue to carry us into new realms of scientific knowledge and bring us ever closer to realizing new technologies of great benefit to society.

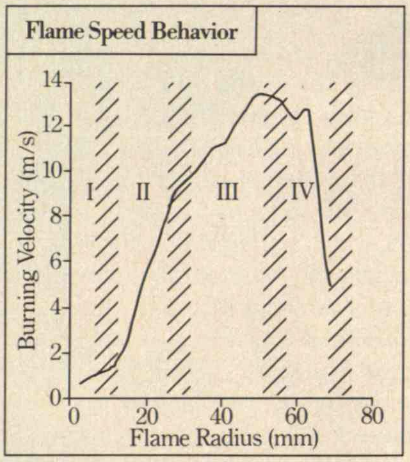
John S. Mayo is executive vice-president of network systems at Bell Laboratories in Murray Hill, N.J. He hold B.S., M.S., and Ph.D. degrees in electrical engineering from North Carolina State University. This article is based on a paper entitled "VLSI: Implications for Science and Technology" (copyright 1979, Bell Telephone Laboratories) that will appear in a forthcoming book, *Communication Society*, edited by Thomas J.M. Burke (Fairfield University Press).

The Turbulence Parameter



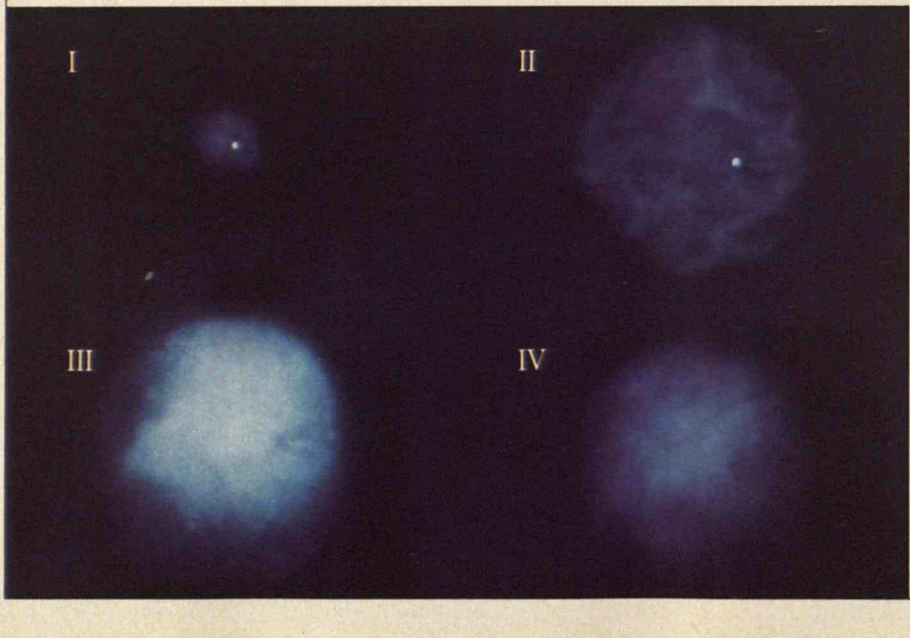
The Turbulence Parameter

Energy-efficient operation of the internal combustion engine requires the highly turbulent movement of fuel and air in the chamber. Recent advances at the General Motors Research Laboratories provide a new basis for determining what degree of turbulence will get the most work from each drop of fuel.



Burning velocity plotted as a function of flame radius. Combustion stages are indicated by roman numerals.

High-speed photographs showing flame evolution (lasting six milliseconds) through four stages: initiation (I); flame growth (II); full development (III); termination (IV).



WITHOUT TURBULENCE, the highly agitated motion of cylinder gases, combustion would take place too slowly for the gasoline engine to function. Predicting combustion behavior in order to design engines with greater fuel efficiency depends upon understanding the relationship between vital, turbulent gas motions and burning rate. The challenge is to quantify this relationship—a complex task made more difficult by the requirements of measuring a transient event occurring in a few milliseconds within a small, confined space.

New knowledge of how turbulence affects flame speed has been revealed in fundamental studies conducted at the General Motors Research Laboratories by Drs. Frederic Matekunas and Edward Groff. Their investigative results have been incorporated into a model that successfully predicts the effect of engine design and operating conditions on power and fuel economy.

The researchers separated their experiments into two phases. In the first phase, they measured turbulence in the engine cylinder; in the second phase, they determined flame speeds over a broad range of operating conditions. Testing took place in a specially designed, single-cylinder engine equipped with a transparent piston to permit high-speed filming of the combustion event.

Hot-wire anemometry was applied to measure the turbulent flows while the engine was operated without combustion. Instantaneous velocities were calculated from the anemometer signals and simultaneous measurements of gas temperature and pressure. More than 400,000 pieces of data were processed for each ten-second measurement period.

The significant measure of turbulence is its "intensity," defined as the fluctuating component of velocity. Because conditions in the cylinder are both transient within cycles and variant between cycles, separating the fluctuating and mean components of velocity is inherently difficult. The researchers overcame this problem by using a probe with two orthogonal wires properly aligned with the direction of the mean flow.

The Level of Might That's Right: An Interview with Jerome B. Wiesner

If the U.S. doubles the number of nuclear weapons and delivery systems, the USSR does the same; if we develop a new weapon, they do, too. We desperately need to break this cycle of escalation before it becomes unmanageable.

THE growing national emphasis on military strength was clearly reflected in the recent presidential campaign. Although the number of defense-related programs envisioned by our president-elect is certainly great — perhaps too great, according to some — the platforms of *both* major parties featured increased military spending in general and deployment of sophisticated new weapons systems in particular. The *New York Times*, expressing its own position this fall in a series of articles under such headlines as "The Nation's Military Anxiety Grows as Russians Gain" and "The Shoddy State of the Armed Forces," quoted Senator Henry Jackson's unambiguous concerns: "We're in a dangerous position of military disadvantage across almost the entire spectrum of military power. And our wounds are largely self-inflicted, the product of a decade of wishful thinking and inadequate action. For fear of crying wolf we have behaved like sheep."

At the same time, Jerome B. Wiesner, who had recently retired as president of M.I.T. (to become Institute professor emeritus), was expressing his dismay at this unnecessary return to the issues and spirit of the Cold War — a great, unabashed reliance on nuclear overkill.

Dr. Wiesner's thoughts have been forged by his many years of involvement in defense policy in the top echelons of the nation's science and technology community — including service in the White House as a member of President Dwight D. Eisenhower's Science Advisory Committee and as science advisor to Presidents John F. Kennedy and Lyndon B. Johnson. Thus, although his contributions to any dialogue on military technology and its place in world affairs are always valuable, *Technology Review* thought that Dr. Wiesner's observations would be especially useful to its readers at this time of political and military change. What follows is the result of a recent conversation between Dr. Wiesner and managing editor Steven J. Marcus.

MARCUS: You recently said, "If I were ever going to write, one of the first things I'd write about is how the Cold Warriors have won." Why have they won?

WIESNER: There's no single reason, but I suppose the most important is widespread *frustration*: despite our great strength in strategic nuclear weapons, we have no viable way of projecting our will around the world, particularly in areas where the Soviet Union intervenes, usually through a surrogate country. In fact, it is the support of indigenous revolutions and the use of surrogates such as Cuba that makes those situations so difficult to deal with.

It has long been obvious to many people, myself included, that if we ever encountered a situation like the current crisis in the Middle East — where we are anxious to protect vital interests — strategic nuclear weapons would be of limited use. Nor, for that matter, would such weapons be very effective if a land

war started in Europe. Nuclear weapons are only useful as deterrents.

The United States and the Soviet Union both have very large long-range nuclear forces and can do enormous damage to each other no matter what. So both are effectively deterred from using these weapons and from taking actions that could lead to their use. To be sure, there are people who believe that if the United States had twice as many nuclear weapons as the Soviet Union, we might then have a meaningful edge that would allow us to dictate conditions to the Soviet Union. I don't believe this. I believe that an effective military presence can only be achieved by creating a truly effective conventional army — backed by a deterrent nuclear force — but this has been the one thing we've never been willing to do. In fact, widespread reaction against the Vietnam War worsened the situation.

We got into the present bind long ago, immediately after World War II, when the Soviet Union retained a very large conventional military force and continued to supply it with modern weapons while neither we nor our allies in Europe were prepared to maintain large conventional armies. So we turned to a nuclear deterrent — "a bigger bang for the buck," as Secretary of State John Foster Dulles characterized it — and that worked as long as the Soviet Union had none or just a few strategic nuclear weapons and inadequate aircraft to deliver them. Also, the U.S. had a major advantage because of its European and African bomber bases, which ultimately turned the Russians to ballistic missiles. I believe we did and still do deter Soviet adventurism. We also did, and still do, deter ourselves.

But after the Soviet Union developed missiles and thermonuclear weapons in substantial numbers, it was unreasonable to expect the United States to invite the destruction of its major cities to stop a Soviet move, if it occurred, in Western Europe. So we countered the larger conventional Soviet forces in Eastern Europe by putting tactical nuclear weapons in Europe — a profound shift with implications most people didn't understand. The deterrent was no longer dependent on strategic weapons but on *tactical* weapons: the almost-certain escalation from a local tactical nuclear war to a strategic nuclear war guaranteed that both sides would be very careful. The Europeans have yet to fully understand this.

But none of this is very useful in a situation such as we have today in the Middle East. We do not have sufficient conventional power to protect the oil fields there should they be threatened. Obviously, if the Soviet Union chose to move into the Middle East, we'd have a good deal of trouble responding effectively; it would be as though we moved into Mexico and the Soviet Union wanted to stop *us*. But it isn't only the geographic disadvantage — the fact is that we have a poorly prepared conventional force. It is this aspect of our armed forces that needs the greatest, perhaps exclusive, attention. For in a serious emergency, we might become desperate enough to try to redress our imbalance with tactical nuclear weapons or even by threatening a general nuclear war, even though the consequences of such a war would be history's greatest catastrophe.

Yet many people — including Senator Jackson, whom you've quoted — continue to advocate the same course of action that has been responsible for so much of our present dilemma: the nuclear arms race, which they still hope we can somehow win. "Winning" no longer means staying strong enough so that nuclear weapons are never used by either side. To many strategists it now means having enough of the right kinds of nuclear weapons so that if an exchange occurred, we could eliminate their missile bases and still retain enough strategic power to destroy more of the Soviet Union than they would of the U.S., and kill more of their people than they would of ours. Planning to fight limited strategic wars, with highly accurate missiles armed with relatively small nuclear weapons, has become the latest craze. Such a battle, if it actually could be limited

Planning to fight limited strategic wars, with highly accurate missiles armed with relatively small nuclear weapons, has become the latest craze.

(and if the Soviet Union accepted our rules of war), would still kill millions of people and do vast damage in both countries. Actually, I believe that such an exchange would almost certainly escalate into a general war.

If you feel comfortable with the prospect that only 60 million or so of us would be killed while twice as many Russians were killed, and only 30 percent of our physical facilities were destroyed in contrast to 40 percent of theirs, then maybe we could get into a position to "win." But such all-out nuclear war would end civilization as we've known it: just the radioactivity and the obliteration of our infrastructure would be such that we would be a long time recovering. And the effects of nuclear fallout would pose major health problems throughout the world.

An Arms Race with Ourselves

MARCUS: What do you think is in the minds of people who now counsel very strongly that the United States should take the nuclear arms race up a few more levels? What inspires their concerns?

WIESNER: Several things have happened. First, the Soviets have increased their missile force greatly. Second, as those of us who tried to get some agreements in the 1960s predicted, weapons have become more accurate and controllable. In the 1960s, it was hard to make a believable argument that a counterforce strike (against the Soviets' or our own nuclear force) was possible: the weapons were too unreliable and their accuracies too poor. Several ballistic missiles per target were needed to have a very high probability of knocking it out. Since then, we have both developed MIRVs (that is, each rocket can now carry a number of warheads, all independently guideable), and guidance accuracies are much improved. So a counterforce attack now looks more feasible. Nevertheless, it's hard to make a convincing argument, even in the face of these new and destabilizing technologies, that the Soviet military could wipe out all U.S. forces. Calculations show that some land-based missiles would be left, and we would also have the bomber- and submarine-based forces, as well as the nuclear weapons on aircraft carriers.

On the other hand, one can create very sophisticated scenarios in which the Soviet Union carries out a surprise attack on our forces but not on our cities. Then they say, "We still have enough in reserve to destroy your cities if you try to retaliate," and the United States surrenders. Military planners who believe in such scenarios would like us to upgrade our capabilities to be able to fight it out and ultimately say "we win."

There are several flaws in this argument, however. Most important is that you can't really have an exchange of nuclear weapons without killing a lot of people. This was the subject of a big debate in 1975 in the Senate Foreign Relations Committee. James Schlesinger [then secretary of defense] had proposed building just such a war-fighting capability. If the Soviets struck our Minuteman force with low-yield, highly accurate missiles, he said, they'd kill only 800,000 Americans — a nice, "acceptable" level. But the committee, with Senators Clifford Case and Edmund Muskie playing a big role, got the Pentagon to do calculations based on realistic assumptions. These showed that even in such an exclusively "military" engagement, many millions of people would be killed, whereupon Schlesinger withdrew the proposal [*see "The Human Costs of 'Limited' War" by I.F. Stone, October, p. 33*].

There is no way to prove that these esoteric strategies can't occur; yet when you realize that *ten* nuclear weapons, properly directed, could badly damage the ten largest Soviet cities (or, for that matter, ours) and kill millions of people, you can see that not many weapons have to survive a surprise attack to pose an unacceptable threat. In fact, hundreds of nuclear weapons and delivery systems would survive even the best-executed surprise at-

We shouldn't spend all our time and energy and money on unnecessary systems. In some ways, we're in an arms race with ourselves.

tack. And this is what people don't recognize when they worry about the size of the Soviet nuclear force. Some strategists attribute magical powers to the Russian planners and especially to their ability to predict how the United States would react to a nuclear attack. We already have sufficient capability to respond massively after a Soviet attack and inflict enormous damage, and if the Russians are as clever as is claimed, they must know this.

We shouldn't spend all our time and energy and money on unnecessary systems. Actually, in some ways we're in an arms race with ourselves! The MIRVs, the high-precision guidance systems, and practically everything else that's carried us from the stable position of the 1960s to this terribly unstable situation today were *our* inventions. We thought that we could improve our security by developing and deploying them. Unfortunately, the Soviet military planners thought that MIRVs were nice and developed them, too. Meanwhile, because of the Vietnam War, the general unpopularity of maintaining large conventional armies, and the fact that we've not been willing to concentrate technology on conventional weapons, our conventional force is inadequate for many purposes. We do have a pretty good navy, but it could be bigger and stronger, too, and like all of the military services, it's in trouble because it cannot recruit and retain adequate personnel.

What we haven't been willing to accept is the fact that nuclear weapons are so powerful that they have changed the entire military picture. It's not rational that nuclear weapons be used, under any conditions, by powers that have large numbers of them. We or the Soviets might effectively threaten some country that doesn't have many nuclear weapons with our overwhelming force, but if we threaten the Soviet Union, we're likely to scare ourselves at least as much as them.

MARCUS: If the deterrent posed by a tiny number of weapons, such as ten, is adequate, then it seems to me that our "arms race with ourselves" is just so much military-industrial-governmental make-work.

WIESNER: Well, the problem is deeper. There is a "positive feedback" process at work involving the U.S. and Soviet planners. Although I must admit that your point has some validity — self-interest is often present, even if only unconsciously — most people who press for more weapons claim to want to enhance our security. But you can also look at it this way: the military planners on both sides have the task of defending their nation, but since there is no such thing as defending a country against nuclear weapons, the best strategy is to get the maximum assurance against their use. And in the view of the planners, the larger your superiority, the less likely the other country is to start a war.

On the other hand, the Soviet Union is not prepared to let us have that advantage. So if the United States doubles the number of nuclear weapons and delivery systems, the USSR does the same; if we develop a new weapon, they do, too. We desperately need to break this cycle of escalation before it becomes totally unmanageable. Each cycle produces a situation more dangerous for both countries. But president-elect Ronald Reagan's professed intention is to regain nuclear superiority. If he means we should build, say, twice as many ballistic missiles, he has to demonstrate either that the Soviet Union won't follow suit (and therefore we *will* feel more secure) or that there is some reason why having twice as many on both sides makes us more secure.

MARCUS: In some of your writing in the 1960s, you questioned the accuracy of intelligence reports on Russian military power. Do you have reason to believe that recent reports of a Russian buildup are any better?

WIESNER: Our intelligence is much better now, too. There *has* been a big buildup of Soviet forces since about 1966. Their power used to be seriously overestimated. We know, for example, that they never had the number of bombers that was claimed in the

1950s; they never had the number of missiles that were claimed in the "missile gap" debates. But there's no question that the Soviets, who seemed at one stage to be prepared to live with a minimal deterrent posture, have made a determined effort in recent years to match our forces and even exceed them, according to some people. There are four reasons, I think.

First, their vastly improved reconnaissance capabilities exposed their weakness. Second, after the Cuban missile crisis, many Russians believed they'd been faced down because of the numerical difference. There was no real strategic threat to either side — I am sure they knew logically that they had us deterred — but their numerical "inferiority" created a psychological problem. (Khruschev was probably fired because of Cuba. My own view is that the Cuban crisis wouldn't have been any different even if the Russians had possessed a lot more missiles. Cuba is close to the United States and important to us but hardly so important to them. We didn't try to help Czechoslovakia or Hungary during their uprisings, much as we would have liked to, even though we had a decided nuclear advantage over the Soviet Union.)

The third reason stems from the major change in the political alignments of the Soviet Union and China. Ten years ago, one of the big arguments for antiballistic missile systems was to help protect the United States from Chinese missiles. I always thought that was foolish, but China now represents a threat to the Soviet Union, not to the United States. So the Soviet planners must now consider two adversaries, the U.S. *and* China, and I'm sure this has had some impact.

For me, the Chinese worry also explains much of the Soviet Union's enhancement of its conventional forces, both in the numerical buildup and the reequipping they have done to a far larger extent than we. This buildup can, of course, be viewed as a threat to Western Europe, but it is more likely a sign of the Soviet Union's increased fears about its own security. The Chinese and the Russians are extremely paranoid about each other; both sides expect that war will break out sooner or later along some part of their long mutual border.

The last reason for the Russian buildup, I think, is that they have much greater control of their resource allocations than we do. Once they start building tanks or missiles, it doesn't seem to be very hard for them to keep going; they just let things run. Also, because the Russian standard of living is not as high as that of the United States, a much bigger share of the GNP can go toward military spending, and their people have little effect on resource allocation.

Noise in the Channel

MARCUS: What should the United States do in response? Better yet, what could we do to help *reverse* the trend?

WIESNER: The sensible thing during the last two decades would have been to make agreements with the Soviets that would limit the numbers of weapons and also the development of much more threatening, sophisticated weapons. We tried to negotiate comprehensive agreements in the early 1960s — an ideal time because the number of weapons was relatively small and they were poor first-strike weapons. Today, with thousands and thousands of nuclear warheads on both sides, and even more sophisticated weapons on the way, conditions for monitoring a treaty have become far more difficult. An ideal agreement would be one in which numbers were limited, nuclear testing was halted, and levels were slowly reduced. If I were president, I would challenge the Soviet leaders to a "peace race," offering to slowly reduce the size of the strategic force as they did the same. Although this would be difficult, it could be done. At least we should not devote a large part of our resources to increasing the number of ever-more-sophisticated, unnecessary weapons.

People forget that the nuclear warhead on a Polaris missile, for example, has the same destructive power now that it had when it was built. Even if the Soviet Union created a more sophisticated weapon that perhaps weighed a little less or was a bit more accurate, the basic U.S. nuclear force would remain an effective deterrent.

MARCUS: So there's no need to augment it?

WIESNER: I don't believe so. I think if we could show some restraint, it's conceivable that we could persuade the Russians to do the same. Americans generally blame the Soviet Union for the arms race, but in general it is the United States that has had the technical initiative (to which the Russians usually later responded).

But I don't know whether the Russians are in a position to agree to anything; they seem to be in a state of disarray. They're obviously very embarrassed by the Afghanistan situation and worried about China. They've got enormous problems in their own country as well as in their satellite countries. The present leadership is old and the replacement process has already begun.

MARCUS: What kind of state do you think *we* are in? If two people were having a discussion like this in Russia, how would they perceive the United States and its motivations?

WIESNER: They would probably say much the same, and I would guess they'd be at least as worried about us as we are about them. In spite of all the fear that has been generated and the fact that we're in serious trouble because we don't have the means for dealing with instability and revolution in areas of importance, the United States has come out pretty well in international competition with the Soviet Union. Egypt, for instance, is no longer aligned with Russia, and the Soviet influence has weakened in many other Middle Eastern countries, too. There has been the dramatic change regarding China: we obviously like our new relationship with the People's Republic of China, but it must be very traumatic for the Russian leaders (it's as if Canada suddenly became an ally of the Soviet Union). We fail to appreciate the unsettling effect that this must have on their thinking — and on their unwillingness to decrease their military power.

MARCUS: In that spirit, might not our present plans for the MX convince the Russians that American strategic policy is now not only hawkish but maybe irrational? I'm reminded of your comment (along with three coauthors — Abram Chayes, George Rathjens, and Steven Weinberg — in ABM: *An Evaluation of the Decision to Deploy an Antiballistic Missile System*): "It's hard to understand why a system with such obvious defects, both inherent and in relation to its assigned mission, should command continuing support from military leaders and, in the last four years, from political leaders as well. It is not easy to answer such a question, and even to begin to do so requires a hard, even a skeptical, look at the processes by which decisions on major weapon systems are made."

WIESNER: Lyndon Johnson's decision to deploy an ABM system — a decision I watched him make — was political. The 1968 election was looming large and the Republicans were attacking him for letting defense preparedness run down, so he took the cheapest choice — the "thin" antiballistic missile system — even though he was told by virtually all the experts that it wasn't likely to be useful. Most people who supported it admit now that the ABM system was no good. Technical experts claim you could build a better one today, at least for hard-point defense [such as of missile silos], and some experts advocate that we do that instead of building the MX. But we'd have to abandon the treaty prohibiting the building of missile defense systems, and that would be a step backward.

MARCUS: Why do Pentagon decision makers want the MX? How do they justify their current approach?

WIESNER: Well, they have those sophisticated scenarios to cope with in which the Soviets, with the

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forces they're building and will deploy in several years, could wipe out the Minuteman and then say to us, "Give in or we'll attack your cities." They reason that if we augment the Minuteman with the MX, we create another 4,000 targets and thus make a Russian first strike impossible. But that would not be true for long; if the Russians wanted to take on 4,000 more targets, they could do so by building more MIRVs. They could also build their own MX system.

I don't believe these very sophisticated tactics are realistic because there is a very high probability that a substantial number of missiles will survive any conceivable attack. Some professional "war gamers" have said I'm naive. They argue that the Russian view of war is different from our own: because the Russians are used to fighting and having millions of people killed, their leaders might launch a war in which the possibility of millions of Soviet casualties is acceptable as long as they can kill twice as many people in the United States. What is unthinkable in the United States, in other words, is supposedly thinkable in the Soviet Union.

MARCUS: Wasn't there a point in 1963 when we could have had a comprehensive test-ban treaty, but, because of some noise in the channel, we missed the opportunity?

WIESNER: There was "noise in the channel," all right: primarily a few influential members of Congress. If they had encouraged President Kennedy instead of threatening him, he probably would have been able to obtain a comprehensive test ban.

MARCUS: It would seem, then, that the Cold Warriors *have* won. Therefore, don't the MX et al. symbolize a national failure to "reconvert" — to direct the capabilities of the "military-industrial complex" to nonwarlike areas? Despite the hopeful talk of the late 1960s and early 1970s, it seems we are still addicted to producing ever-more-sophisticated weapons simply because the people involved need something to do.

WIESNER: I don't think that's it; we *could* put the people to work in other areas. I think we failed in not understanding the value of halting the arms race and in not concentrating our energies where we could excel: in creating an adequate life for all people. The only arena in which we now feel competent, it seems, is the arms race; our society is so complex we don't even understand how it works, much less how to deal with the problems of the Third World.

This was obvious in the recent campaign: candidates were reluctant to make explicit commitments regarding economic and social issues because these are areas in which voters have some firsthand experience and can make their own judgments. On the other hand, most voters have no firsthand knowledge about nuclear weapons or Russian intentions, and they must therefore accept, to a much greater degree, what the candidates say. At such a moment, when the country is frustrated by its own internal problems and lack of international influence, we revert to militarism and nationalism. Pragmatic politicians take a low profile; almost every politician who could be a spokesperson for the sensible course of action is afraid to speak out. Hubert Humphrey once told me, many years ago, that the only time he nearly lost an election was when he voted against an increase in the bomber force in the early 1950s.

Information Power

MARCUS: How do we bridge the "information gap"? You've talked a lot in the past about a two-sided coin: on the one side, an invasion of privacy; and on the other, a barrier between the public and the information it should rightfully have. You've even said that secrecy — inaccessibility to information — is a very large factor in the continuation of the arms race.

WIESNER: I think it is. The public should be informed of the facts, including the intelligence data,

Americans generally blame the Soviet Union for the arms race, but the United States has usually had the technical initiative, to which the Russians later responded.

on which many of the arguments for more weapons are based, and here is the real dilemma and challenge. Most public information comes from one-sided, off-the-record briefings and leaks. Moreover, I don't believe that the "media" — newspapers, journals, and television — know how to deliver a really sophisticated, complicated message such as that involved in understanding the arms race, or the energy problem or the inflation problem, for that matter.

Many broadcasters say there's no audience for in-depth programs on such subjects, but I think there's a need for experimentation on how to provide the public with the information it needs. The energy situation, for example, is sufficiently complicated that it can't be explained in a two-, three-, or four-hour show or a single newspaper or magazine article.

And the same is probably true of the defense issue: it would take a lot of examination, discussion, and debate to give people enough information so that they could independently judge the likelihood of the Russians launching a preemptive strike and the need for new weapons to reduce that risk. If the issues are important enough, and the presentations done well enough, it seems to me that viewer or reader interest will take care of itself.

MARCUS: You've often described yourself as an optimist. Do you still?

WIESNER: Yes, I still think it's unlikely that we'll have a nuclear war. It is a little more probable now than in the past because, until recently, neither we nor the Soviet Union had anything at stake that would justify risking the holocaust. The Soviet Union wasn't likely to invade Western Europe, and we weren't likely to try to free their Eastern European satellites by force. Whenever we got into trouble in the past — in the Middle East or Cuba, for example — both sides realized that things should not, and need not, get out of hand. We worked hard to avoid direct confrontation. But now the West has an enormous stake in what goes on in the Middle East, and the temptation on the part of the Soviet Union to take advantage of the chaos there must be very great. Yet this very situation might make everyone finally realize that nuclear weapons are unusable. My judgment is that when the issues become sufficiently vital that the use of nuclear weapons (even "limited") seems justified, people will try desperately to avoid it, even at high cost.

MARCUS: You're optimistic that nuclear war will not be waged intentionally, but what about its accidental initiation? Did you feel any alarm last June, for example, when equipment failure caused a serious state of alert for our bombers?

WIESNER: That didn't alarm me very much because I know something about the control system and its safeguards — at least I did 15 years ago, when I was last deeply involved — and the system has many fail-safe features. For example, even after strategic bombers have taken off, pilots cannot arm their weapons without being sent coded information. The nuclear weapons on missiles are similarly protected: even if a rocket got fired by accident, its weapon would almost certainly be unarmed.

MARCUS: That's not true of a submarine-launched missile, is it?

WIESNER: I think it probably is, though I don't really know the details of the modern control system. But I can only believe that it has been made safer. Of course, no one likes to have these false alarms, but I don't believe they really represent a major step toward . . .

MARCUS: . . . Armageddon?

WIESNER: Yes, I think the American control system has enough built-in security so that an accidental nuclear war will not be caused by us. I hope that the Soviet Union has provided similar safeguards.

MARCUS: Whenever I ask experienced arms-control people whether they think complete disarmament could ever be possible, their answer is some variation on: "We have opened up a Pandora's box,

and there's just no way to get the evil back in."

WIESNER: I don't believe we can go all the way to zero nuclear weapons until there is a very different political situation in the world.

MARCUS: You used to think so, didn't you?

WIESNER: No.

MARCUS: In your *Daedalus* piece of 1960 ("Comprehensive Arms-Limitation Systems"), it struck me you were very strongly hinting at it.

WIESNER: No, I was saying that we should go back to a small number of warheads — I picked the number 200 — because I don't think there is any way to guarantee that potential adversaries haven't hidden a few warheads (and even if they don't have any, they could build two, five, or ten very quickly). An agreement to retain a modest number of weapons on both sides could be adequately verified if both sides wanted it. At that level, even a 50 percent change in the actual number would not change the security of the deterrence.

This is the best we could do at present (it would be quite an improvement), because until there is a much more effective international organization, total disarmament — either of conventional or strategic weapons — is just not feasible.

The National Preoccupation

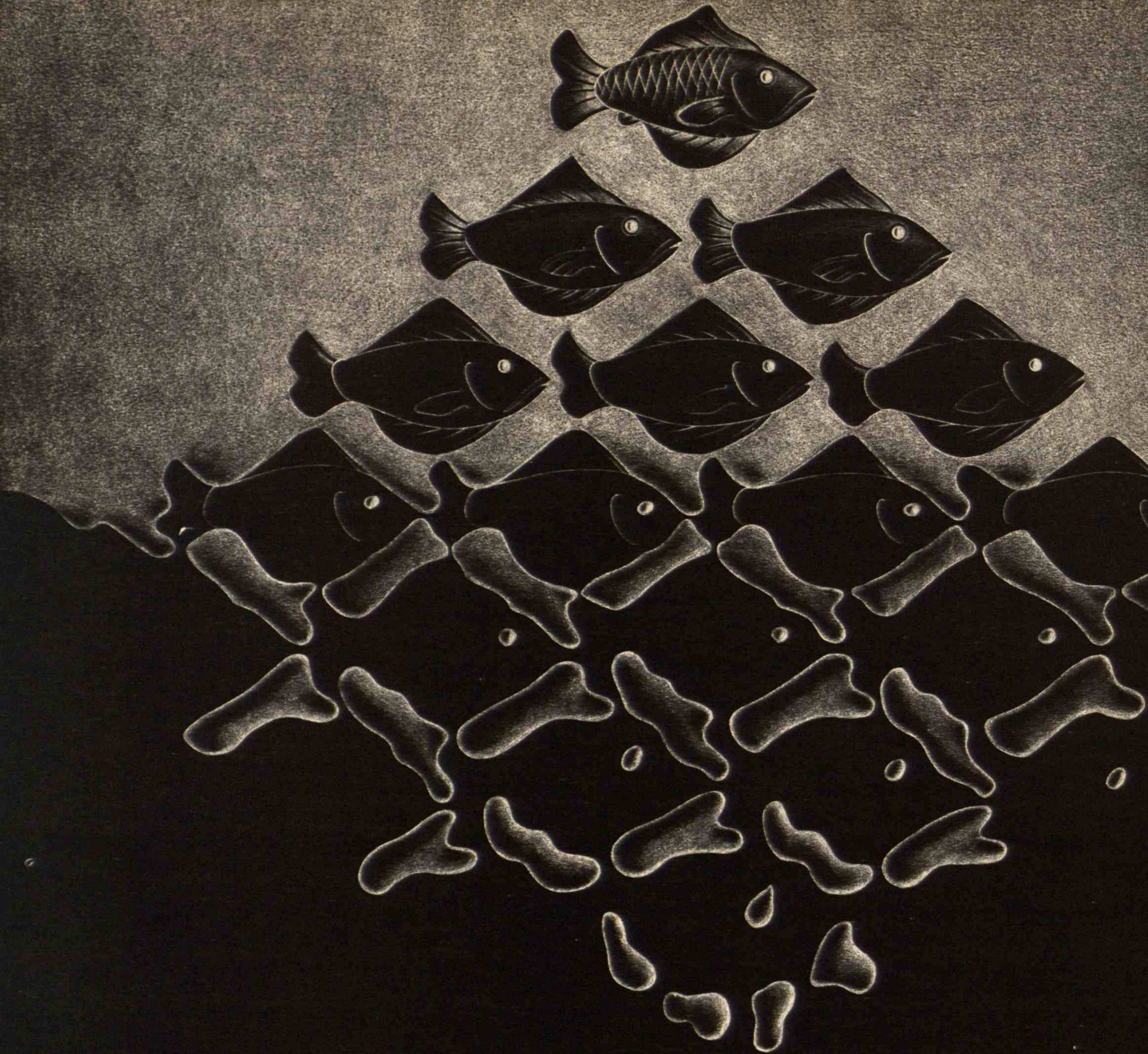
MARCUS: Some economists have been arguing that the falling levels of productivity and innovation in the United States have been caused, in large measure, by excessive military spending. Their logic is that while the Germans and Japanese, for example, have invested in commercial enterprises with great multiplier effects, we've placed much of our resources into defense projects that drain, rather than enhance, the national economy. Do you think there's something to this?

WIESNER: It's a hard case to make. One could also make a strong argument for the other side: that the most innovative industries in this country have been those closely related to military needs: semiconductors, aircraft, and computers, for example. At the same time, although they are only 5 percent of our GNP, the defense industries engage a substantial part of our technical capability and draw the most creative people away from the civilian industries.

I once asked a very distinguished Japanese industrialist how he explained his ability to design better products than we did, and he said, "I can hire all those very good engineers from the University of Tokyo to work on consumer products. In your country, those graduates all go into the defense industries."

I wish it were that simple, but I think our productivity problem stems more from our lack of vision. The American steel industry, for example, has long viewed its market as captive and had no real incentive to modernize, while the Japanese steel industry has taken the *world* as its market. The same has been true of the American automobile industry, which felt secure in its enormous captive market. Meanwhile, Japanese automakers had to respond to worldwide trends to find their proper niche, and consequently developed cars better suited to today's conditions.

American industry has been unbelievably slow in recognizing the competitive drive of foreign industry, and I think this failure is due to the maturity of the industries — the lack of concentration on productivity and competitiveness. Clearly, we did not realize until recently how hard other nations were striving to displace us as industrial leaders of the world. A national preoccupation with defense may have contributed to this, but I believe this is only one of many factors. I am concerned, however, that international matters — including military affairs — have tended to get more attention from the president than all but the most pressing domestic problems. □

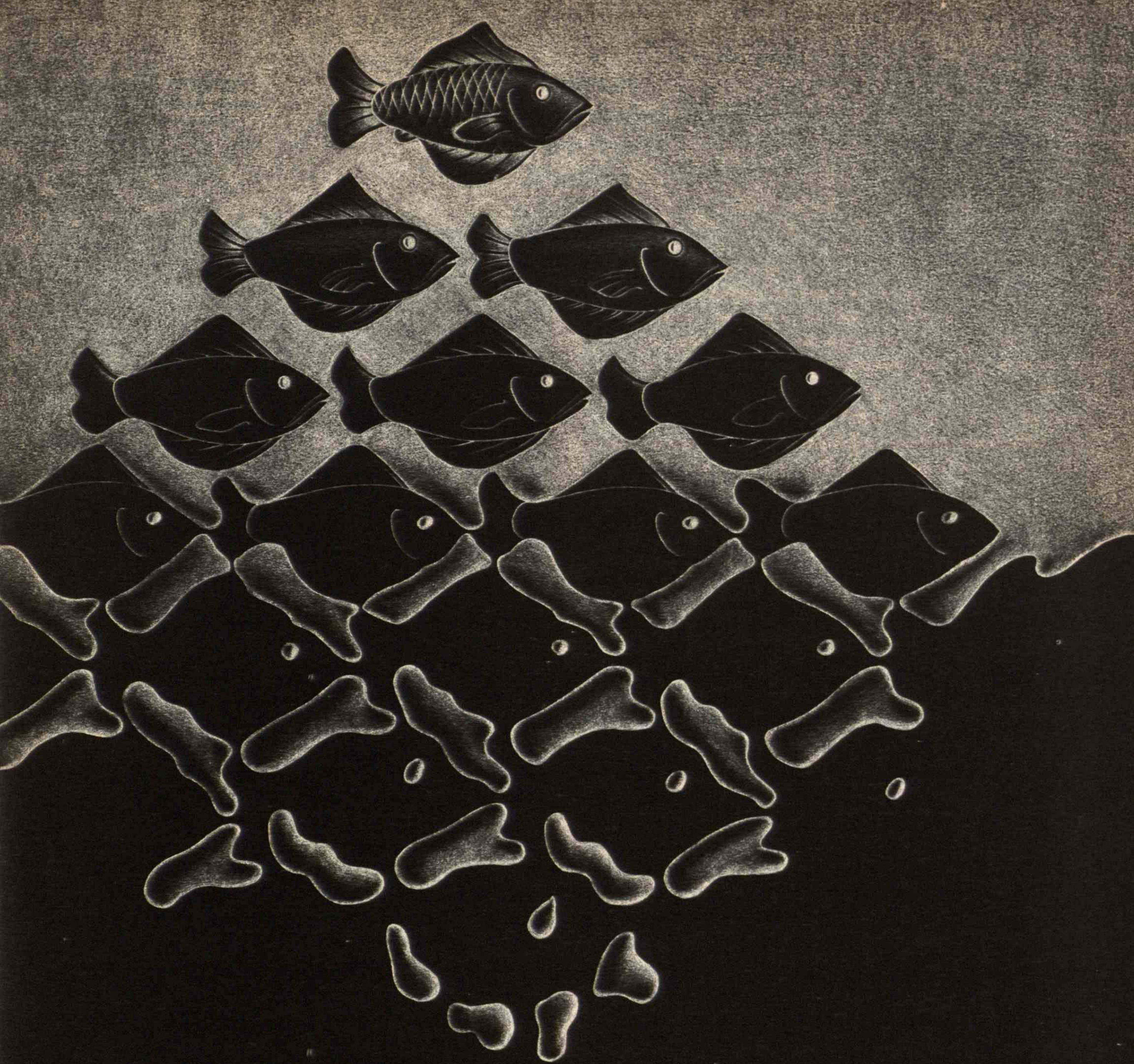


Fish versus Fuel: A Slippery Quandary

by Robert W. Howarth

Fragile marine environments must be protected from chronic oil leaks if their role as a major food supplier is to continue.

Illustrations: Michael Emerson



THE debate over the effects of oil pollution on commercial fisheries has intensified greatly in recent years. On one side, the oil industry shows the public pictures of fish swimming around oil rigs in the Gulf of Mexico and asserts that fishing there is as good as ever. On the other side, environmental groups and the states of Massachusetts and New York have filed suits against the federal government to obtain more protection against what they perceive as threats from offshore oil development to commercial fisheries and other living resources.

In fact, little evidence of major damage to a commercial fishery can be unambiguously traced to oil pollution. Yet the paucity of evidence cannot be taken as proof of lack of damage. Rather, it may reflect the difficulty of studying the links between oil pollution and fisheries, particularly when such links are subtle. For example, the massive oil spill along the Brittany coast of France which resulted from the breakup of the *Amoco Cadiz* in 1978 caused obvious and widespread damage to commercial shellfisheries and finfisheries. But less encompassing damage would have been much more difficult to link causally to oil pollution.

Considerable oil also enters the ocean from the atmosphere, in routine runoff from oil tankers, in runoff from urban areas, and as waste from coastal industries. Little study has been directed at these chronic sources, and comparatively little thought has been directed toward minimizing them.

No offshore oil spill has ever been cleaned up to any significant extent.

Oil has been produced off shore in the Gulf of Mexico for over 35 years. If oil pollution can damage a fishery, there should be no better place to witness these effects than in the Gulf. And indeed, contrary to statements of oil industry representatives, the fisheries of the Gulf of Mexico have developed unhealthy signs. Although fish catches there have remained steady for years, much more effort and energy is required to catch the same tonnage of fish. For instance, according to a 1975 report of the National Academy of Sciences, the average daily catch of shrimp per boat dropped from almost 14 tons per day in 1950 to just 3 tons per day in 1972. The harvest of oysters per area of grounds fished dropped steadily from 560 kilograms per hectare in 1945 to 64 kilograms per hectare in 1972. But are these effects the result of oil pollution? There is virtually no way to know. Other possible causes include other forms of pollution, overfishing, natural fluctuations, and the destruction and alteration of marshlands.

Despite the limited evidence linking oil pollution directly to fishery damage, there is a growing consensus that the potential for serious harm is real. To recognize the potential threat, however, one must first understand the chemistry of oil and its behavior.

While it is estimated that over 6 million metric tons of oil are introduced into the world's oceans every year, we do not know if this amount is increasing, remaining constant, or decreasing. However, much more oil enters the oceans now than 20 years ago, or even than during World War II, when tankers were frequently torpedoed.

Surprisingly, tanker accidents account for relatively little ocean oil pollution, perhaps only 2 to 4 percent, according to estimates by a National Academy of Sciences panel in 1973. Likewise, in an average year, offshore oil production probably accounts for only 1 to 2 percent of the oil introduced into marine environments.

The largest quantity (over 90 percent) of oil entering the oceans is from chronic pollution sources. These include discharges from oil refineries and other industries, runoff from city streets, rainout of pollutant hydrocarbons from the atmosphere, and the routine discharges and leaks associated with transporting oil by tanker. These chronic inputs are less dramatic than the occasional accidental spill, and they therefore escape the attention of the press and the public. But the cumulative consequences of chronic oil pollution may be more severe than those of the more dramatic spills.

Our understanding of the behavior of oil in seawater and its effects on the marine environment is far from complete, and most of what we know has been learned only in the last decade or so. We do know that oil is toxic to a variety of organisms at very low concentrations. Thus, oil spills can seriously disrupt marine ecosystems, and the effects of such disruptions can be long lasting. Oil itself can persist for decades in marine sediments following an oil spill.

The See-No-Evil Fallacy

Oils are complex mixtures of thousands of organic compounds. Despite over 30 years of effort, chemists have not been able to separate and characterize all these compounds. Most oil consists of compounds made of hydrogen and carbon — hydrocarbons — though some constituent compounds also contain oxygen, nitrogen, or sulfur. Hydrocarbons are only very slightly soluble in water, and oils are less dense than water. Consequently, when oil is spilled, it will tend to form a slick on the surface.

A variety of processes can cause an oil slick to disappear gradually. These might include evaporation, mixing or dissolution into the water below the slick, chemical or biological degradation, adsorption into particles in the water, or incorporation into the fecal pellets of tiny animals that ingest oil drops. While these processes make the oil less noticeable, they may not render it less harmful. Following an oil spill, public attention usually focuses on the slick, and with its disappearance, worries about its deleterious effects disappear. This "out of sight, out of mind" reasoning is not justified. For example, the use of chemical dispersants may increase the oil's harmful effects by making it more likely to come in contact with marine organisms.

Until recently, evaporation of oil into the atmosphere was assumed to be the major cause of slick breakup, but actual measurements of evaporation were rare. Recently, carefully controlled studies in artificial ecosystems, such as those used in the Marine Ecosystems Research Laboratory (MERL) at the University of Rhode Island, have challenged this assumption. These large tanks of seawater with muddy sediment at the bottom are designed to du-

Below: The demonstrated effects of low concentrations of oil compounds on marine organisms.

Organism studied	Concentration of water-soluble oil components (parts per billion)	Observed effects
Macro-algae	0.2	Reproduction inhibition
Snails and crabs	1	Elimination of normal feeding behavior
Snails	4	Interference with chemoreception
Fish eggs (plaice)	10	40% mortality after a few days' exposure
Phytoplankton	10-40	Inhibition of growth, dramatic change in morphology
Fish (marsh mummichogs)	125-200	Alteration of metabolic systems
Amphipods	300-400	Reduction in reproduction

plicate the natural ecosystems of a coastal bay, but the fate of oil added to them can be more readily determined. The evaporative loss of oil from these tanks, though less than expected, was significant during the summer; the loss during the winter was much smaller. Although the diminished wave action in these controlled systems relative to open waters may have decreased evaporation, these findings suggest that evaporation may be more important in warm southern waters than in cold northern seas. Although evaporation does disperse an oil slick, the oil hydrocarbons are not lost from the environment but are merely transferred to the atmosphere. Ironically, the cycle may close with oil being deposited back into the ocean by rainfall.

While the solubility of most of these compounds is quite low, some will nonetheless gradually dissolve into the large volume of water. The compounds that are most water soluble also tend to be the most toxic, perhaps because once dissolved they are readily available for intake by organisms. A number of studies have indicated that dissolved oil can be toxic at very low concentrations; as little as 10 parts of oil compounds dissolved in a billion parts of water have been shown to cause death in some organisms. And concentrations of water-soluble fractions of oil as low as 0.2 to 1 part per billion have been shown to be detrimental to certain life processes in a variety of marine animals, plants, and bacteria. The oil concentrations in many coastal areas near urban or industrial centers are in this dangerous range. Concentrations of oil hydrocarbons below the slick from the *Argo Merchant* spill (off the coast of New England in December 1976) were as high as 250 parts per billion.

Oil not only dissolves but is mixed into water as suspended drops. Depending on the type of oil and weather conditions, a range of mixtures can result, some mostly water, others mostly oil. Waves increase this phenomenon, and in a storm oil drops can be driven as deep as 80 meters. The mixing of oil drops into the water greatly increases the rate at which the oil dissolves because the surface area of oil exposed to water is thereby increased.

Some species of zooplankton — the tiny, free-floating animals of the sea — are known to feed on these oil particles. The oil is concentrated in their fecal pellets, and when the pellets sink to the bottom, the oil sinks with them. A typical population of zooplankton (two individuals per liter) grazing on an oil slick can transport three tons of oil per square kilometer per day to bottom sediments.

Particles suspended in the water column can also absorb and transport oil. Although the oil itself will float, the oil-sediment combinations are heavier than water and sink to the bottom. Most of the few attempts to examine this process have found that oil is transported to the bottom quite rapidly.

Studies have shown sediment contamination around offshore oil platforms, even in the absence of major oil spills, and sediments near urban centers have also been shown to be highly contaminated with oil hydrocarbons. For example, Dr. John Farrington and his colleagues at the Woods Hole Oceanographic Institution revealed that the surface sediments just offshore from the Statue of Liberty in New York are about 0.1 percent oil (dry-weight basis). Most of this oil probably results from sewage sludge and contaminated dredge spoils.

Oil degradation by chemical processes and the action of bacteria is often a very slow process. Some hydrocarbons are produced by living organisms, so it is not surprising that organisms are also able to decompose hydrocarbons. Yet the hydrocarbons produced by living organisms differ from those found in oil in several ways. Oils contain a much

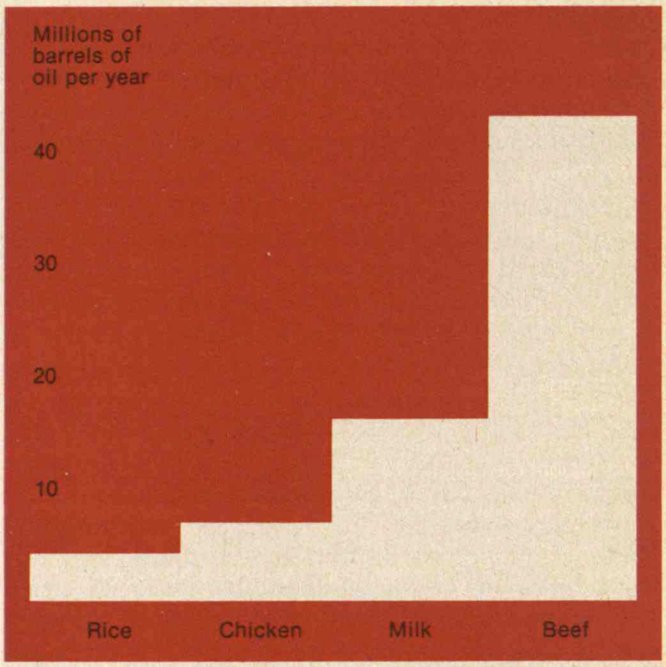
more complex mix of hydrocarbons, including a class called aromatics. Not found in uncontaminated organisms, aromatics include the most water-soluble, environmentally persistent, and toxic compounds in oil, some of which are carcinogenic. This may seem paradoxical since oils are derived from biologically produced materials. However, oils have undergone geochemical changes over very long periods of time at high pressures and temperatures, and in this process a vast new array of hydrocarbons is produced.

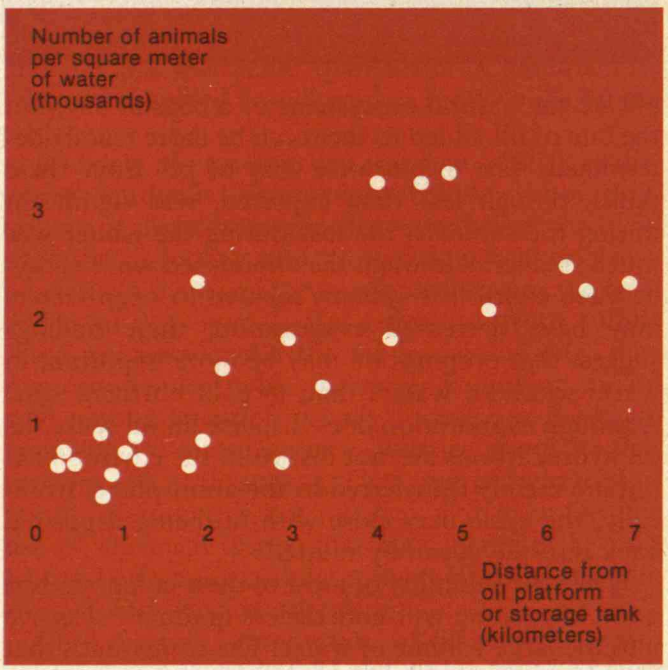
A decade ago it was commonly assumed that as oil "weathered" — by the processes of evaporation, dissolution, and degradation — its immediate toxicity decreased. Research conducted during the last few years casts doubt on this assumption. In many cases, the decomposition of oil hydrocarbons can result in new, more toxic substances containing oxygen atoms as well as atoms of carbon and hydrogen. Some of these new substances are potentially carcinogenic as well, and many are more water soluble than the parent hydrocarbons. Consequently, although degradative processes will speed the disappearance of an oil slick, they may also increase the concentration of toxic and carcinogenic compounds.

Toxicity Studies: A Murky Business

The scientific literature on laboratory studies of oil toxicity is immense, yet many of these studies are of little use in determining the likely effects of oil on natural systems. In most toxicity studies, the actual concentration of oil hydrocarbons to which an organism is exposed is not measured. An investigator may typically add five milligrams of oil to a liter of water and assume the concentration is five milligrams per liter. But some of the oil may evaporate, some may float on the surface, and some may adhere to the wall of the container. Thus, the actual concentration of hydrocarbons may be less than assumed.

Many studies have ignored sublethal effects and instead have attempted to determine only the concentration of oil that causes the death of 50 percent of the individual organisms, the so-called "LD-50" studies. This approach can be quite misleading, since sublethal effects can occur at far lower concentrations than fatal ones and can be quite damaging in natural systems. However, sublethal effects are more difficult to study. Documented effects of low concentrations of oil include the inhibition of





Top: Much of the food produced in the U.S. is produced at a very high energy cost. For instance, it takes 26.2 gallons of milk to produce one kilogram of milk protein. New England's fisheries are by comparison highly energy efficient: an average of only 0.53 gallons of oil are needed to catch one kilo of fish protein. Consequently, replacing fish protein caught annually on Georges Bank would be costly.

Bottom: The effects of chronic oil releases from oil development in the North Sea on ocean-dwelling animal communities.

The cumulative consequences of chronic oil pollution may be more severe than those of the more dramatic spills.

growth of various types of phytoplankton (microscopic plants of the ocean), reduced reproduction of some marine animals, and interference with feeding behavior and communication among animals.

Some types of organisms can tolerate pollution and stress better than others. An ecologist calls such organisms "opportunists" because they take advantage of opportunities to grow and reproduce with relatively little competition from species that cannot tolerate a stressful situation. Toxicity studies often use opportunistic species because they are much easier to grow under stressful laboratory conditions. These studies will obviously not reflect possible harm to less adaptable organisms.

Animals are often more sensitive to the effects of oil at one point in their life cycle than another. Adult fish, for example, appear to be more tolerant of oil than fish eggs and young larvae, which are easily poisoned by very low concentrations. Many toxicity studies fail to take this into account. Also, many oils undergo rapid oxidation when exposed to strong ultraviolet light such as that found in sunlight at the surface of the ocean, and this photo-oxidative degradation has been shown to increase the toxicity of the oil. Almost all laboratory toxicity studies have been carried out under artificial light, which contains considerably less ultraviolet light than sunlight. Consequently, the photo-oxidation of hydrocarbons to more toxic substances is much less than would occur in an oil slick on natural waters, and the potential toxicity of the oil may be greatly underestimated. Dramatic evidence of this was obtained by Richard A. Larson and colleagues at the Philadelphia Academy of Sciences, who demonstrated that the toxicity of an oil to yeasts was increased fourfold in just one day by exposure to an ultraviolet light source approximating that found in nature.

Representatives of the oil industry have attempted to persuade the public that although refined products such as home-heating oils can have toxic effects, crude oils (oils straight from the ground) are relatively nontoxic. For example, during a public meeting in New England to allay fears about offshore oil development, a representative of the Environmental Protection Division of Texaco said that "the oil found on Georges Bank would be crude oil, which is not dangerous." This position is unfounded. Refined oils are derived from crude oils, and the same toxic components found in the refined oils are also found in the crudes. Many refined oils are actually more toxic than crude oils, and the degree of toxicity will vary among crude oils from different fields and regions. Regardless of the type of oil, the components that dissolve into the water tend to be the most toxic. There is no evidence to support the petroleum industry's assertion that the dissolved oil compounds found below a slick from a crude oil spill are less concentrated than those from a refined oil spill. The *Amoco Cadiz* spill of crude oil had massive toxic effects.

What effects can oil have on a commercial fishery? Perhaps the most obvious is the contamination of fish with oil. Marine organisms, including commercially important fish and shellfish, will accumulate oil hydrocarbons in their tissues. These fish and shellfish pose a public health hazard because some of these hydrocarbons are carcinogenic. In severe cases, contaminated fish and shellfish will taste of oil, but the lack of such a taste does not guarantee safety. Contamination of shellfish with oil components often leads (or should lead) to the closing of commercially valuable fisheries. Following a small spill in West Falmouth on Cape Cod, portions of the shellfish beds were closed to harvesting for more than ten years.

High Mortality of Fish Eggs

While evidence of adult finfish killed by oil pollution is rare when compared with that of shellfish, the toxic effects of oil on fish eggs and larvae have been documented. A Russian scientist, Oleg Miranov, demonstrated in 1968 that concentrations of only 10 parts of oil in a billion parts of water can cause death among a significant percentage of fish eggs.

Very few studies have been made of the death of fish eggs or larvae from exposure to oil pollution, and since the fish eggs and larvae are very tiny, their death can easily be overlooked. However, a study of the *Argo Merchant* spill by Dr. Crosby Longwell, a scientist with the National Marine Fisheries Service, showed that a high percentage of fish eggs underneath or near the oil slick had drops of oil sticking to them. An average of 20 percent of the cod eggs and 46 percent of the pollock eggs were either dead or dying. A study after the *Torrey Canyon* spill in 1967 showed 50 to 90 percent mortality of the eggs of the commercially important pilchard. However, it was not known whether this resulted from the toxic effects of oil, the dispersants used to "clean up" the

Several Ounces of Prevention

RECENT Coast Guard estimates show that as much as 85 percent of all oil entering the oceans from tankers is from routine discharges. The most significant pollution comes from the release of ballast — water taken into the ship's hold to balance and weigh down the boat after its cargo is unloaded.

In the past, ballast water was routinely pumped into empty cargo holding areas coated with oily residue from previous hauls. When the ship was in high seas, it would release its dirty ballast directly into the ocean.

In the mid-1950s, a new method called "load on top" (LOT) was introduced, whereby ships could hold ballast in "slops" tanks, where the oil was decanted and pumped back into the cargo area to supplement the next load.

While the LOT method is said to have significantly reduced chronic tanker pollution, critics complained that it simply wasn't effective enough.

The grounding of the *Argo Merchant* in late 1976 brought the issue to a head. The public cry for action focused primarily on the federal government, and in March 1977, President Carter ordered an interagency oil-pollution task force to review the problem. Evidence brought to light by this investigation led to the passing of the Port and Tanker Safety Act of 1978, which essentially put into law terms negotiated at the International Conference on Tanker Safety and Pollution sponsored by the United Nations earlier that year.

In addition to mandating the installation of segregated ballast holds, the 1978 ruling requires the cleaning of cargo areas with high-pressure jets, improved steering mechanisms to minimize collisions, and inert gas systems to allow ships to replace the flammable gases in dead-air spaces above their petroleum cargo. All new crude oil tankers over 20,000 tons were required to carry these improvements immediately, and ships of all ages must install them no later than January 1, 1986. According to Coast Guard sources, these measures should greatly reduce the amount of oil in the world's oceans. — *E.R.S.*

spill, or some unknown factor. Dr. Longwell has examined mackerel eggs in the chronically polluted waters of the New York Bight off New York City and found egg survival to be poor in most areas. Oil pollution may or may not be a contributing factor to this problem.

While such mortalities are disturbing, we do not know enough about the basic biological controls on fish populations to determine their seriousness. Fish populations vary greatly from year to year: the production of new young fish of a particular species is low most years but is occasionally very high. The new fish produced in any given year are called an age class, and high production of new young fish is called a strong class. Most of the commercial fish catch is from these strong age classes. The factors that cause their appearance are not well known and may vary from species to species and region to region. An adult female fish produces a tremendous number of eggs each year, most of which die. Does the mortality of fish eggs caused by oil pollution increase the total mortality of fish eggs and larvae and therefore decrease the resulting number of adult fish? Or when oil kills some fish eggs or larvae, do those remaining have a higher chance of living (density-dependent mortality, in the language of an ecologist)? The answer may vary among fisheries, but any additional source of mortality to fish eggs is likely to cause at least some decrease in age-class size.

Upsetting the Balance

In addition to its possible direct effects on fish, oil may subtly change the ecosystem supporting a fishery. One such change is a shift in the types of phytoplankton in a water body. Experiments with artificial ecosystems have demonstrated that a variety of low-level pollutants can cause the replacement of relatively large species of phytoplankton with much smaller species. Oil concentrations as low as 20 parts per billion had this effect in the artificial ecosystems. Such replacement also occurred temporarily following the *Torrey Canyon* spill and appears to be occurring in the North Sea, perhaps owing partly to chronic oil pollution from tanker traffic and coastal industries.

Why should we care about changes in the phytoplankton community? Many oceanographers suspect that such a shift might induce a change in the types of animals found further up the food chain. This could result in the replacement of commercially important fish with jellyfishlike animals (such as ctenophores and salps) which are, at present, of no direct use to humans. Thus, a subtle growth inhibition of some phytoplankton species by low concentrations of oil might lead to large decreases in the catches of commercial fisheries.

Oil can also have major effects on the animals that inhabit the bottom sediments, effects that may go

unnoticed by the untrained observer. Many commercially important fish depend on bottom animals for much of their food, so changes in the composition of these animal communities can affect a fishery.

One of the earliest and best studies of this effect was conducted by Dr. Howard Sanders and his colleagues at the Woods Hole Oceanographic Institution following the small spill in West Falmouth, Mass. in 1969. The spill caused a massive kill that rendered some areas of sediment completely devoid of animal life. These areas were repopulated within a few months, but the new animals created a very different community. At first only one species lived in the affected area — a pollutant-tolerant, opportunistic species of worm common in polluted harbor sediments, one of the few animals viable in the oil-contaminated sediments near an oil refinery in Los Angeles harbor. While some other animals reappeared relatively quickly, the bottom community had still not fully recovered to its original state six years after the spill, which occurred in an area of soft bottom sediments capable of holding onto the oil and thereby slowing recovery. And a 1973 study of the 1957 *Tampico Maru* spill conducted by Dr. Wheeler North of the California Institute of Technology showed that the recovery of some affected rocky areas may not have been complete after 16 years. As of 1973, mussels and green abalone had yet to repopulate some of the regions.

Chronic discharges accompanying offshore oil development also can affect the community of bottom animals. An oil-industry-sponsored research project in the Ekofisk oil field in the North Sea since 1973 has shown a decrease in both the individual animals and species of animals found near an oil platform, apparently from contamination of the sediment (*see the chart on page 72*). With increasing distance from the rig, the effect becomes less severe.

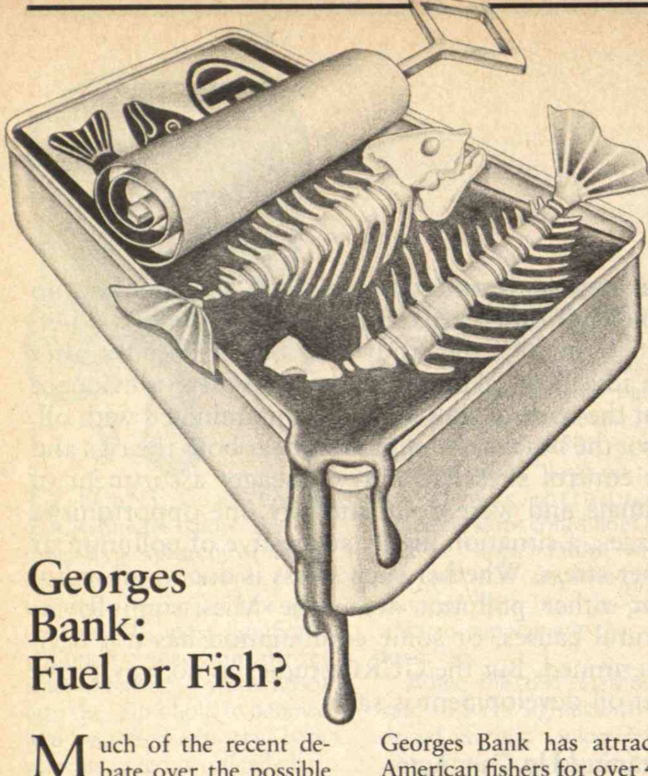
Is a similar effect observable near rigs in the Gulf of Mexico? The oil industry has sponsored work to address this and related questions through the Gulf Universities Research Consortium (GURC), and the research summaries for public release assert that no chronic deleterious effects were found near rigs. This message has been widely advertised and disseminated to public officials. However, Dr. Howard Sanders recently documented the flaws of this research in the *Journal of Marine Research*. The GURC studies compared the bottom communities near rigs with other control sites, and, finding no significant differences, concluded that oil had no effect. However, the study was begun decades after the advent of oil development, and there is evidence that the control sites are also contaminated with oil. Also, the bottom communities near both the rigs and the control sites had only a meager assortment of animals and were dominated by one opportunistic species, a situation highly suggestive of pollution or other stress. Whether such stress is due to oil pollution, other pollution from the Mississippi River, natural causes, or some combination has not been determined. But the GURC studies in no way prove that oil development is safe.

Cleaning Up Our Acts

To what lengths should we go to protect our fisheries? A major source of oil pollution comes from chronic releases from tankers. A normal tanker will carry oil in its tanks on one leg of a voyage, and after unloading this oil, will fill its tanks with water to gain stability for the return voyage. Before oil is reloaded, this water and its oil contaminants must be dumped. Such discharges could be avoided by using segregated ballast tankers — tankers with two separate types of tanks. One set of tanks would carry oil to port, and another set would be filled with water for the return voyage: oil and water would never be mixed. Although not common, such tankers are presently in use. According to a 1978 study, the use of such tankers might increase the cost of oil by 0.5 to 0.6 cents per gallon, but the benefits are clearly worth the cost.

Other pollution sources may be more expensive to avoid. For example, during oil exploration and development, drilling muds with many toxic constituents are routinely dumped from rigs. These muds can be barged ashore, but the cost can be high. For example, Beth Mullin of Yale University has estimated that barging costs for Georges Bank could be as high as all other costs of drilling combined. Current regulations call for the use of the best available, economically feasible technology to minimize pollution. Is it economically feasible to double the costs of drilling? Perhaps so when one compares the value of the fishery with the potential profit from a well.

What can be done to minimize the harmful effects of oil pollution? A first step is to recognize that oil-



Georges Bank: Fuel or Fish?

Much of the recent debate over the possible effects of oil pollution has centered on Georges Bank, one of the world's most productive fisheries and a region now slated for offshore oil exploration. Lying some 150 to 250 miles off New England, Georges Bank is a relatively unpolluted portion of the continental shelf. It is regarded as a very treacherous piece of water because strong tides and waves interact over the shoals, which are only ten feet beneath the ocean's surface in some locations. Yet Georges Bank has attracted American fishers for over 400 years, as well as large foreign fishing fleets. This foreign competition led to pressure in the 1960s and 1970s to expand our territorial boundary from 3 to 200 miles offshore.

Just why Georges Bank is so productive is not clear. One reason might be that phytoplankton production there is among the highest measured for any oceanic region, providing the food chain with a very strong base. The dominant species of phytoplankton is very large, which allows for efficient passage of energy to the fish. Georges Bank is also a major breeding and nursery ground. At its peak in the early 1970s, the fish catch there was the highest per unit area for any major fishery in the world. By comparison, the fisheries in the Gulf of Mexico are much more diffuse, with the average catch per unit area perhaps one-tenth as great.

We cannot predict what oil development will do to Georges Bank; we know too little about the basic biological controls on the fishery and the way oil will affect them. However, according to government estimates, a rather small find of oil is expected, perhaps a little more than 120 million barrels from the leases sold so far. If that oil were used at one time, it would supply the country for only three to four days. A field that small and so far offshore will be only marginally profitable relative to other oil fields. Consequently, developers will use cheaper technology, which might lead to a higher percentage of oil discharged into the environment. Tankers rather than pipelines will transport oil ashore, and unless special tankers are used, the chronic release of oil may be high. The Department of the Interior estimates that perhaps 0.4 percent of all the oil developed will be lost in chronic small spills and routine, legal discharges associated with loading tankers.

Although not confined by any land masses, Georges Bank is a distinct body of water defined by a semiclosed circular current pattern, or gyre. Within the gyre, water moves in a clockwise fashion, taking about three months to complete a revolution. Most commercially important species of fish on Georges Bank have buoyant eggs and larvae that float along passively for four to five months while they develop into juvenile fish, making an average of one and one-half revolutions around the bank. Consequently, nearly all the fish eggs and larvae will be carried through the areas of oil development and exposed to chronically polluted waters that may have high-enough

spill cleanup operations are not the answer — no offshore spill has ever been cleaned up to any significant extent. Even in protected waters, less than 25 percent of spilled oil has been recovered, according to Robert Stewart of the National Oceanic and Atmospheric Administration. Present cleanup technology is largely ineffective when waves are greater than 6 feet, winds are greater than 20 knots, currents are greater than 1 to 2 knots, or ice is present. And unfortunately, significant improvements in this technology are not likely in the near future.

From both an economic and ecological viewpoint, a better approach to reduce the damage from oil pollution is to minimize the chronic discharge of oil. Most such attempts have failed, largely because public attention has focused on the spectacular oil spills rather than on less obvious chronic pollution.

The world's oil reserves are limited, and our society will probably be forced to rely largely on nonpetroleum energy sources within the next few decades. Unfortunately, the problems of hydrocarbon pollution may not end with the demise of our oil-based economy. Pollutant hydrocarbons are released into the atmosphere when coal is burned, and much of this pollution can end up in the oceans. In fact, recent work has indicated that a significant percentage of the hydrocarbon pollution in coastal sediments may result from burning coal. If Western coal is shipped to urban areas in pipes as water slurries, new problems may result from disposal of the hydrocarbon-polluted water at the end of the pipelines.

It is urgent that engineers develop procedures for minimizing releases of pollutant hydrocarbons into the environment. But, beyond that, society must address some basic questions. Should polluting indus-

concentrations of oil to cause significant mortality. Some government officials have argued that the Georges fisheries will be adequately protected by prohibition of oil development in the spawning grounds. While such protection is important, it will hardly be sufficient. All of Georges Bank serves as a nursery ground for the fish, and because of the gyre, it needs to be protected as a unit.

Those who would extrapolate from the Gulf of Mexico to Georges Bank would be well advised to study some of the basic biological differences between the fisheries. On Georges Bank, most fish eggs and larvae tend to float near the surface, where exposure to high oil concentrations is most likely. The life histories of the commercially important fish and shellfish of the Gulf of Mexico are very different. The larvae of the important species (menhaden, oysters, and shrimp) develop in wetlands and estuaries, so offshore oil spills are less likely to damage a fishery. Menhaden eggs float at the surface for only a couple of days and then develop into larvae and move up into the estuaries.

The gyre on Georges Bank is tighter some years than others; that is, the amount of water exchanged off the bank varies. John Colton and Robert Temple, then with the U.S. Bureau of Fisheries in Boothbay Harbor, Maine, suggested in 1961 that the age classes of fish on Georges are tied to the integrity of the gyre. They believe that when the gyre is tight, fish eggs and larvae are held within the highly productive waters, and a good age class results. When a good deal of water is exchanged, more fish eggs and larvae are carried off into the less productive waters where survival is lower. Therefore, conditions that would normally lead to a large age class — a tight gyre — could also cause an accumulation of oil from chronic discharges, which might kill more eggs and larvae. The result might be a series of mediocre age classes and decreases in the year-to-year variability. This would hurt the commercial fisheries but would be very difficult to attribute to oil.

How does one compare the value of a fishery with the value of oil? The dollar value of the Georges Bank fishery, in terms of the annual catch reported, is probably comparable to the value of the oil from the leases sold thus far. But industry and government have argued that we should develop the oil since "every little bit counts." To assess this argument, we can compare the energy value of the oil with the energy cost of replacing the fishery.

Much of the food produced in the United States is obtained at a very high energy cost. For instance, it takes 26.6 gallons of oil to produce one kilogram of beef protein and 8.7 gallons of oil to produce one kilogram of milk protein. By comparison, the fisheries of New England are a very efficient food-producing system. On average, only 0.53 gallons of oil are needed to produce (catch) one kilogram of fish protein, even when costs such as the energy used to build the fishing boats are included.

What if we were to pursue the "Texas alternative," drilling for oil on Georges Bank and replacing with beef any protein lost because of damage to the fishery? Because the energy costs of producing beef are so much greater than those of catching fish from Georges Bank, the Texas alternative may not prove practical. At its peak in the early 1970s, 1.8 billion pounds of fish (the equivalent of 70 billion grams of protein) were caught on Georges Bank every year. To replace this with beef protein would cost 42 million barrels of oil per year, almost seven times more oil than is expected to be produced from the present lease sale.

Oil development will not completely wipe out the fish on Georges Bank, but a significant reduction in catch is possible even with stringent safeguards, and the net energy gained may not be significant. In fact, as we develop oil fields that are more and more marginal, we run the risk of losing more energy than we gain.—*R.W.H.* □

tries be spread out along our coast, or should they be concentrated in already environmentally degraded areas to protect the biological resources of more pristine regions? As cheap energy becomes scarcer, natural biological systems, including fisheries, will become increasingly valuable. We must recognize their value and take steps to protect them.

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Robert W. Howarth, staff ecologist at the Marine Biological Laboratory at Woods Hole, has a Ph.D. in biological oceanography jointly from M.I.T. and Woods Hole Oceanographic Institution. He has been an active conservationist for five years, and testified before the U.S. Senate as a representative of the Conservation Law Foundation in December 1979.

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National Security

Chemical Warfare: Let the User Beware

Chemical agents of death designed for military use are not likely to pass from this world with the dispatch they proffer on their victims. A new technological development has brought confusion and uncertainty to current efforts toward a treaty that would ban their production and possession.

It is strange that the threat of chemical warfare (CW) is with us at all, because the use of poison gas has been outlawed since 1925 by the Geneva Protocol (ratified by the United States in 1975). But some of the treaty's signatories are not confident that others will hold to its terms.

The U.S. Congress, following the rec-

ommendation of the House Armed Services Committee, last September appropriated a total of $22.15 million for the construction of a factory at Pine Bluff, Ark., for production of a controversial new CW ordnance called a binary shell; of that sum the Senate has approved $3.15 million. Such a shell contains two constituents of the nerve-gas agent GB, or sarin, in separate canisters that rupture when the shell is fired, mixing in flight to produce the gas. Construction has not yet begun and the facility hasn't yet received authorization to produce these weapons, but its funding "represents a major shift in attitudes . . . toward such munitions," Matthew Meselson, professor of biology at Harvard University, told an M.I.T. seminar late last fall.

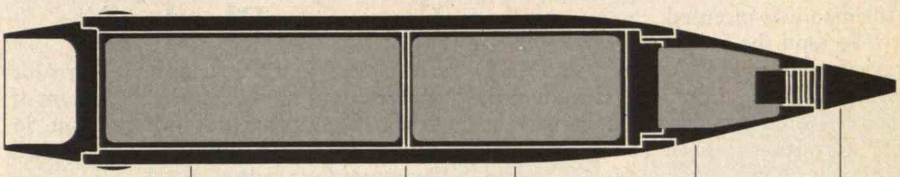
Not since 1969 has the United States produced any CW agents for its own use, and the Soviet Union, "so far as we know," has not produced any during the past decade, said Professor Meselson. But both nations hold large stockpiles — there are some 35,000 tons of CW agents in the U.S. alone — and "most chemical munitions have a long shelf life," he said.

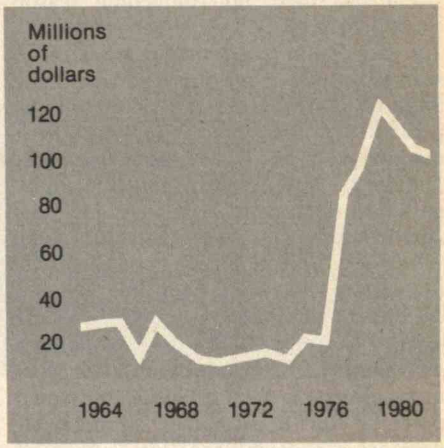
If we have such stockpiles, why all the bother to build new production facilities? According to *Defense & Foreign Affairs*, there is strong suspicion in defense circles that CW agents have been used recently in Eurasia, and that U.S. Army planners concluded — and convinced Congress — that our forces should be equipped with a sufficient quantity of CW weapons as a counterbalance to the perceived threat. Despite its domestic stockpiles, the United States has very little CW potential outside its borders. Except for France, Western European nations do not possess CW capabilities and permit only limited stockpiling of conventional CW munitions by the U.S. The U.S. binary shells should be acceptable to our European allies for stockpiling in their countries, say its proponents, because until loaded with their full complement of chemical components, they are safe to store and transport.

However, Professor Meselson told the seminar that it is "irresponsible" for the United States to pursue a large-scale CW program, which he estimated could cost from $4 to $6 billion. He is concerned that availability of binary chemical weapons could lead to greater military interest in chemical warfare, carrying with it "needless" risks. Against forces with modern protective equipment and good training, chemicals would be only marginally effective in causing casualties, he said. Downward drift, "mistargeting," and residual effects could pose a much greater hazard to unprotected civilians than to the enemy. A cloud of nerve gas may take up to an hour or more to pass and, unlike chlorine and phosgene, "whiffs are additive" in the body, exacerbating the threat to civilians, he said.

A dozen rounds of talks on chemical arms control in Geneva since 1976 between the U.S. and the Soviet Union give some cause for hope that escalation of the CW threat can be defused. There has been agreement in principle between the two nations to ban deadly and incapacitating chemicals, but not "irritant and riot-control gases, which are useful for domestic control purposes," according to *Defense & Foreign Affairs*.

The remaining stumbling block to the drafting of even a limited treaty is the perplexing challenge of agreeing to verification procedures. A factory producing chemical-warfare agents looks much like any other chemical plant. Indeed, the constituents of binary shells are relatively common chemicals that are also useful for industrial purposes, adding to the confusion and the challenge. — *L.A.P.* □





Facing page: U.S. Air Force security police officer in a protective chemical-warfare suit, photographed during a recent test (called "Salty Pets") of chemical-warfare defenses at Ramstein Air Force Base in Germany. (*Photo: U.S. Air Force, courtesy* Defense & Foreign Affairs)

Right: U.S. expenditures for equipment designed to protect military troops from the effects of chemical-warfare agents. In 1977, following the first discussions between the U.S. and the Soviet Union on chemical disarmament, the U.S. spent as much on such equipment as over the five previous years combined. **Above:** Diagram of a binary shell. Contents of the canisters mix after firing to produce nerve gas. (*Data: Matthew Meselson*)

When Agencies Collude

On the surface it seemed nothing more than a simple clash of values, but the reverberations could be heard throughout the entire academic community. When Leonard Adleman, assistant professor of mathematics at M.I.T. (on leave at the University of Southern California), submitted a routine grant proposal to the National Science Foundation (NSF), he suspected the request would be reviewed by experts at the National Security Agency. What he didn't realize was that the NSA would offer to fund the proposal itself.

Adleman studies computational complexity — specifically, why some mathematical problems are so intrinsically difficult that they cannot be unraveled quickly by a computer. This kind of research leads naturally to cryptographic applications, the deciphering and construction of codes, in which the NSA has an understandable interest. After cautioning NSF representatives that Adleman's research might have national security implications, the director of NSA, Vice-Admiral Bobby Inman, called the

mathematician to explain that his agency was interested in funding the proposal. Adleman was incensed.

"To send the proposal to the NSA for review is normal," Adleman told *Technology Review*. "But the idea that the agency would get involved in this way was not an option implicit in my agreement with the NSF." Adleman said he repeatedly refused the NSA offer because of that agency's prerogative to classify research, a step he described as "drastic."

"In this case, no compelling reason existed to classify," Adleman explained. "In this country, the classification of research is such a serious step that there must be more than a matter of opinion justifying it." Adleman maintained he is determined to keep his work in the public domain because of its potential for protecting individuals from unauthorized scrutiny by foreign and domestic agencies. "We're in the midst of an information revolution, the tools of which are the computer, the integrated circuit, and the satellite," he said. "The result is that more and more powerful information is stored in the electronic media. This leads to great potential for abuse, and cryptography provides a powerful tool for combatting such abuse."

Sparked by the publicity surrounding Adleman's objections, representatives of the NSF and the NSA met with White House science advisor Frank Press to discuss how the agencies should handle cryptography proposals. NSF representatives have since drafted a statement resulting from that meeting, that, in summary, states that all such proposals will be forwarded to the NSA for review, which will have the option of offering to fund them. However, researchers, including Adleman, will be permitted to choose either NSF or NSA funding until the NSA sets up an autonomous funding procedure to which scientists can apply directly.

Meanwhile, both agencies are pondering the charge of collusion in the Adleman case. "An award from us is not that different from an award from NSA," insisted Jean Hudson, special assistant to acting NSF Director Donald Langenberg. "If something developed in a project we had funded that we believe might pose a threat to national security, we would send it over to the NSA anyway, and they would have the option of classifying it." Hudson admitted, however, that the NSF had never forwarded any proposal or part of a proposal specifically for classification review. — *E.R.S.* ☐

Strategic Stockpile or Security Blanket?

The United States depends on imports for 98 percent of its manganese, 97 percent of its cobalt, 89 percent of its chromium, 86 percent of its tin, 70 percent of its nickel, and more than half of its oil . . .

. . . A scary situation, which makes it easy to argue for stockpiling these and other materials: If the United States were cut off from foreign supplies by an adversary, we would have to meet essential military needs from a strategic reserve. And if the United States were threatened economically by a cartel such as OPEC, a stockpile would go far to defuse an embargo.

But these simple ideas turn out to be not so simple.

How large should stockpiles be? How do we decide when a stockpile is to be used and when saved for an even greater threat? How can stockpiles be protected from misuse motivated by politics or economics?

The political question arose with vigor in 1973, when President Richard M. Nixon reduced stockpiles of aluminum, copper, nickel, zinc, lead, and silver to a one-year — instead of a three-year — supply. Skeptics charged him with liquidating the easiest-to-sell resources to help pay for the Vietnam War.

Today, stockpile targets are back at their pre-Nixon levels, the goal being to cover needs during an emergency lasting as long as three years. But considerable confusion and controversy remain.

What if a stockpile is exhausted in mitigating an embargo, and then a true military threat materializes? This question strikes at the source of much present confusion, say Amos A. Jordan, Robert A. Kilmarx, and Dan Haendel of the Georgetown University Center for Strategic and International Studies. Too often both purchases and releases of alleged strategic minerals are related to economic or political purposes that have little relevance to security needs, they charge.

One possible solution is to have *two* stockpiles — one military-strategic and one economic. But even advocates of an independent stockpile to reduce our economic vulnerability admit that military and economic reserves would be "difficult to separate in practice," write Messrs. Jordan, Kilmarx, and Haendel in *Comparative Strategy*.

And for what catastrophe are we preparing — an embargo of an essential mineral for price-fixing purposes, a three-year conventional (nonnuclear) war, a short, intensive military effort, or a nuclear war?

Today's strategic stockpiles may well be appropriate to only one of these scenarios — a conventional war lasting three years or more. Stockpiled minerals could hardly be extracted, processed, and manufactured into military material in a shorter period; what's needed is a reserve of armaments, not minerals. And a nuclear war could so traumatize the nation's industrial capacity that stockpiled minerals could never be used.

To try to resolve some of these ambiguities, Messrs. Jordan, Kilmarx, and Haendel call for a broad reassessment of national mineral stockpile policies. Without it, they argue, today's stockpiles are hardly more than an illusionary security blanket for American technical and military strength. — *J.M.* ☐

Transportation

Urban Transit: From One Fad to the Next

Sin′gle-mode ad′vo·co′sis. *A disease of urban and transportation planners, chiefly of Americans since World War II.*

To understand our urban transport problem, says Professor Vukan R. Vuchic of the University of Pennsylvania, begin with the simplest case — a human settlement of cabins along a single path. Two things are needed: the path, and a small cabin that can move from place to place along it.

For those who cannot drive their own cabins, a professional driver.

When congestion becomes a problem, a larger path, or perhaps a second path; or some larger mobile cabins, so that one big one replaces many little ones.

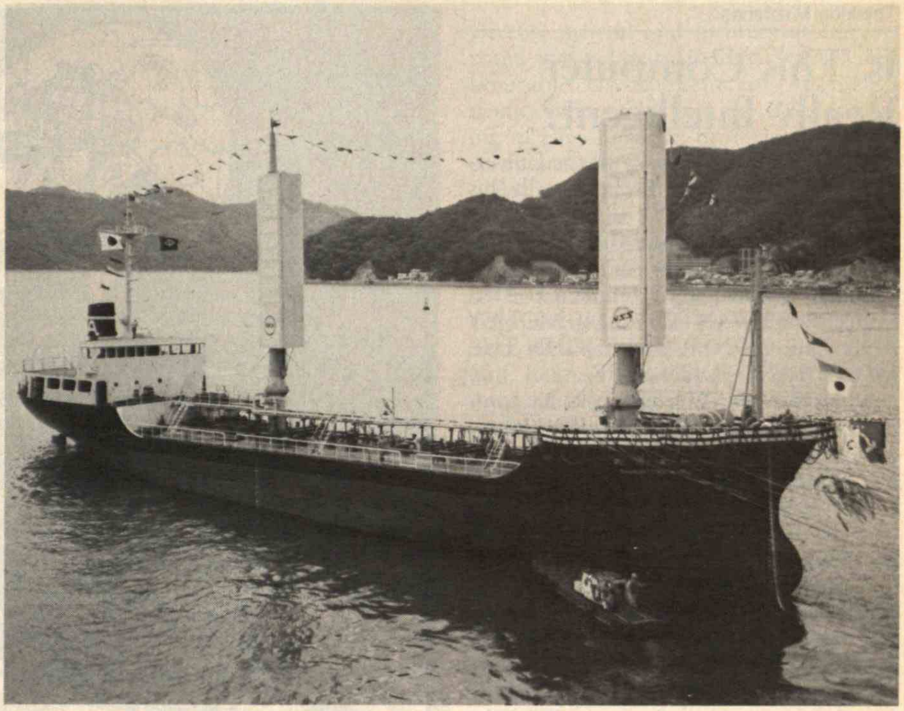
When congestion again arises, a special path for the larger cabins, perhaps coupling them together into still larger units.

As readers may realize, Professor Vuchic is tracing the course of urban transit history in a very oversimplified way. But with a difference, he says: Americans have clung far longer than the cabin travelers of his example to the single-cabin mode — the automobile. They built their cities around it, unmindful of the effects of this single-mindedness on other urban needs. Automobile owners became a vast, gov-

ernment-sponsored club that collected dues from its members and used the proceeds for their benefit. No one stood up for the nonmotorists' rights, and traffic engineering became a skewed art instead of the science it could have been — and was in Europe.

Finally, there was a revolution in the late 1960s and 1970s, when urban dwellers tardily realized that they did not have the kind of cities they wanted. First San Francisco and then Washington turned to expensive new subway systems, and other cities were about to follow suit when San Francisco's BART turned in a lacklustre performance. So now the herd is stampeding in a new direction, dictated by the new concept of transportation system management (TSM), a means of adapting the present mixture of modes to meet changing needs — with minimal capital investment.

Gripped by single-mode advocosis, we still fail to put our priorities for urban transportation where they belong, Professor Vuchic told an M.I.T. seminar last fall. We use too much energy debating the virtues — and especially the costs — of mode versus mode, when the real problem is to understand the urban needs of today and tomorrow and to move decisively toward the modes that are and will be appropriate. — *J.M.* □



The *Aitoku-Maru*, the world's first sail-equipped ocean tanker, features two sets of rigid sails that unfurl automatically under favorable wind conditions. A microcomputer controls the sails' trim, setting them to the most advantageous direction for maximum wind utilization. While the sails might appear small when furled, as above, they were designed for maximum efficiency and are capable of propelling the 900-ton ship at speeds greater than 12 knots.

Oil Under Sail

There is good news for those who yearn to go down to the sea again but hate to make waves. The Japanese-based Aitoku Co. has launched the "world's first sail-equipped tanker," a small, two-masted vessel with an auxiliary diesel engine that is already transporting oil to ports along the Asian coast.

The *Shin-Aitoku Maru* is equipped with a pair of plastic sails linked to the ship's 1,600-horsepower engine via a microcomputer. When wind velocity reaches 5 meters per second, the engine automatically disengages, the sails unfurl, and the tanker proceeds on sheer wind power — at a rate of 12 knots or more.

Aesthetics aside, the main virtue of the sail-supplemented ship is fuel efficiency. While experts consider Aitoku's estimates of a 50 percent fuel savings as "overly optimistic," even the most conservative observers agree that a 10 percent cut in fuel consumption is inevitable *(see "Sail Power for the World's Cargo Ships," March/April 1979, p. 22).*

Nonetheless, some critics doubt that sailing ships will prove as practical as they are romantic. Jerome Milgram, professor of ocean engineering at M.I.T., told *Technology Review* that no existing sailing vessel can approach the 30,000 to 40,000 horsepower required to move large tankers through rough waters at a reasonable speed, and that even if such vessels could be built, they would be prohibitively labor-intensive.

"It really makes no sense to go with sails," Professor Milgram said. "Under rough conditions, efficiency would be cut drastically because so much time and energy would have to be spent just on adjusting gear."

At 900 tons, the *Shin-Aitoku Maru* is a mere infant in oil carrier circles, where the largest tankers reach sizes of up to half a million tons. The boat avoids the roughest waters by sticking close to the coast, and if winds reach 20 meters per second, the sails curl protectively and the engine takes over. But Robert Scher, a research associate in naval architecture at the University of Michigan, is convinced that much bulkier and more versatile sail-equipped tankers could eventually prove practical. His group has studied the possibility of sailing cargo ships since 1974, when the first "oil crisis" threw the idea of alternative power sources headlong into the public arena.

"If the sails save the ship just 10 percent in fuel costs, a large tanker of 250,000 tons would realize about $4,500 in savings per day," Professor Scher explained. "Our study showed that labor costs do not have to increase significantly. After all, these modern ships are automated . . . no one is going to have to climb the rigging."

Yet he cautioned that larger ships will require sails of a size and strength not yet available and might pose speed and safety problems not yet explored.

"The Japanese ship is not a true sailing ship, it is a sail-assisted motor boat," Professor Scher said. "There is a good deal of research to be done before we can expect to launch a really large sailing cargo ship. But certainly the *Shin-Aitoku* is a step in the right direction." — *E.R.S.* □

Thinking Machines

Is This Computer Really Intelligent?

Professor Robert Wilensky of the University of California at Berkeley tells his computer a story:
JOHN NEEDED SOME MONEY SO HE GOT A GUN AND WENT TO A LIQUOR STORE AND HE TOLD THE OWNER HE WANTED SOME MONEY AND THE OWNER GAVE JOHN THE MONEY AND JOHN LEFT.

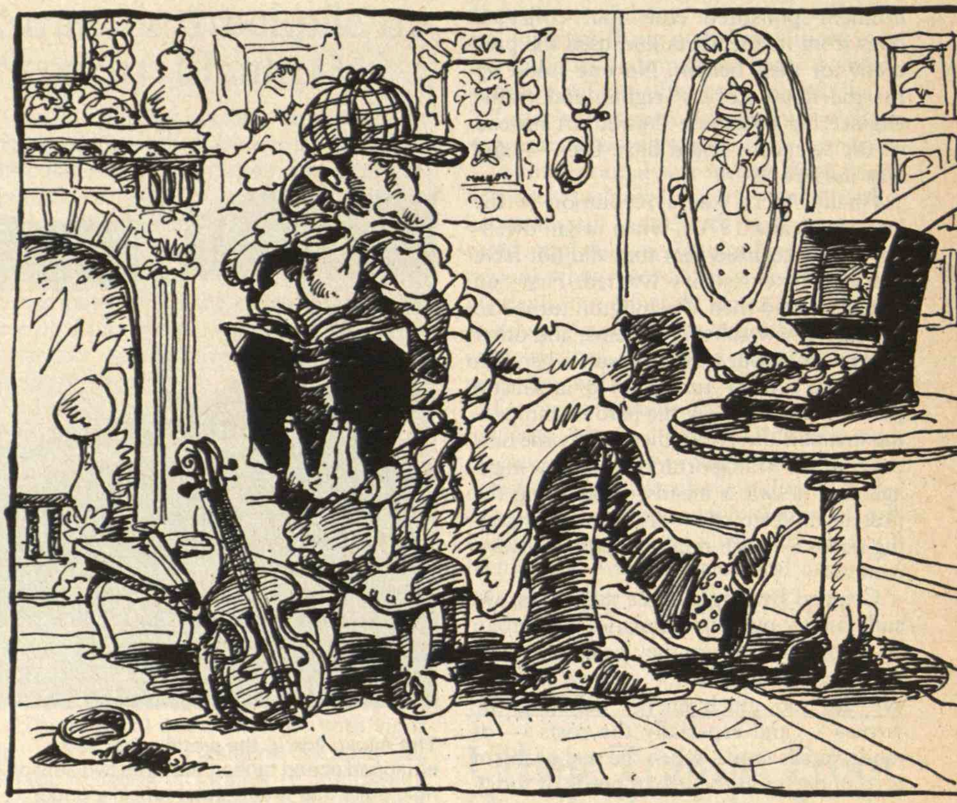
Now Professor Wilensky asks his computer a few short questions abut John's adventure:
Q.: WHAT DID JOHN DO AT THE LIQUOR STORE?
A.: HE ROBBED IT TO GET SOME MONEY.
Q.: WHY DID THE OWNER GIVE JOHN THE MONEY?
A.: THE OWNER WAS AFRAID JOHN WOULD HURT HIM.

His computer apparently knows more about the story than Professor Wilensky has told it. Does this mean that the computer has intelligence?

Professor Wilensky ducked that question at the 1980 meeting of the American Association for the Advancement of Science. The computer program he wrote — PAM — simply incorporates a sense of how people analyze and reason. PAM recognizes the gun as a threatening weapon and presumes that it represents the presence of a threat. (In another version of the story, the computer is told that John took his gun into the store and was given $25 for it. This time PAM concluded that John was selling his gun, not using it in a robbery.)

Gregg Edwards of the National Science Foundation turned the question of artificial intelligence into another: whether the computer was *augmenting* human intelligence, instead of simply interpreting and repeating it. And then Dr. Edwards came face to face with a dilemma: for a computer to augment human intelligence, it must deal with a truly massive volume of data. That requires selectivity — the ability to decide what is relevant and what is not; and selectivity may be a privilege that some people would rather not grant to a computer.

PAM, despite its sense of how the human mind works — at least when presented with questions in realms it understands — is by no means so selective that it can



augment its designer's intelligence. Nor is any other computer in the artificial intelligence sweepstakes today.

That kind of capacity, even in a very limited discipline requires immense computing capacity — more than is yet available. "We would never try to make a computer program for solving Sherlock Holmes mysteries," said Professor Edward Feigelbaum of Stanford University. "To do that it would have to know everything about everything." Richard Hayes-Roth of Rand Corp. put it this way: "The brain is an existence proof," he said, "for a gargantuan machine that we have yet to build." — *J.M.* □

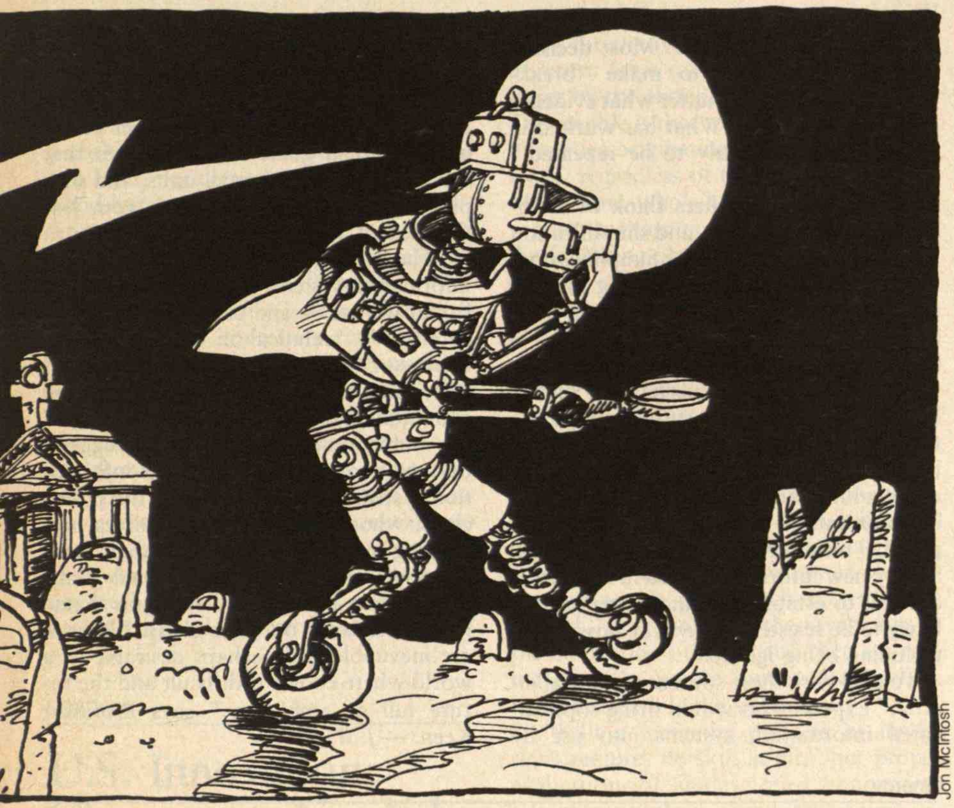
From Robots to Telepersons

You are wearing a comfortable jacket lined with sensors and tiny motors. Each motion of your arm, wrist, hand, and even fingers is sensed, a signal transmitted, and your motion reproduced at another place by a mobile, mechanical hand. Light, dextrous, and strong, this mechanical hand has sensors of its own, and the transmission path linking your hand to its mechanical counterpart returns signals from its sensors so that you can feel and see what it is doing and finding.

Yet "telepersons" are no science fiction dream. The basic ideas have already been worked out in artificial intelligence laboratories such as that at M.I.T. and others at Stanford, Carnegie-Mellon, and Edinburgh Universities. Computers have been equipped with hands and eyes and taught to recognize objects, interpret simple mechanical assembly instructions, and cope with changing spatial relations or moving obstacles.

Multiplied a hundredfold or more so that it encompasses many of a human's powers of moving and sensing, this vision from Professor Marvin Minsky of the M.I.T. Artificial Intelligence Laboratory becomes what he calls a "teleperson" — a remote, operating proxy for your body that can go where you cannot or do not want to and do what you would like to if you could be there.

"Using such an instrument, you could 'work' in another room, another city, another country. Your remote 'presence' could have the strength of a giant or the delicacy of a surgeon. Heat or pain would be 'translated' into informative but toler-



Jon McIntosh

able sensation. Dangerous jobs could become safe and comfortable," says Professor Minsky, alluding to work in mines, the depths of the ocean, and reactor cores. "We can shape a new world of health, energy, and security." And if we work aggressively on the needed technology, this vision could become a reality in 10 to 20 years at a cost of about $1 billion.

We already have some precursors of Professor Minsky's "telepersons" — "crude" (his word) robots for handling radioactive materials and more sophisticated robots used in manufacturing. But these relatively simple human surrogates are not yet versatile or dependable enough. "No present system has any true sense of 'feel,' " says Professor Minksy, and none makes use of the new concepts of "responsible software" by which a machine automatically corrects itself by comparing what it is doing with what it is supposed to do.

The big problem is "to improve our 'teleperson' instruments so they can feel and work like our own hands," says Professor Minsky. The first ten years of his two-decade timetable would be spent in research on sensors, control therapy, automatic monitoring and manipulation, software, and what he calls "human report interfaces" — the problems of translating human motions to a machine and a machine's senses to a human. By 1984 there could be several experimental prototypes of hands and arms and by 1988 some second-generation prototypes given mobility by legs.— *J.M.* □

Microelectronics: The Japanese Connection

In the race to capture large shares of the world market for microelectronic devices and applications, Japan, by most accounts, is the country most likely to overtake the United States, which presently enjoys a commanding lead. This prospect may take on shades of a recurring nightmare for U.S. manufacturers, who have watched the Japanese automobile and electronic appliance industries make substantial inroads into the American markets for these goods.

From the Japanese point of view, however, the game plan for a microelectronic monopoly is not necessarily a sure bet. Certain societal and institutional factors could make Japan in some ways a less favorable environment for microelectronics innovation than the U.S., according to Hiroshi Inose, professor of electrical engineering at the University of Tokyo.

Professor Inose described for a recent seminar at the M.I.T. Sloan School of Management several significant differences between the microelectronics industry in Japan and in the U.S. For example, large corporations in Japan have profited from the close cooperation of government and financial institutions, but smaller firms tend to lack such advantages, particularly important to the development of high-technology products. But in the U.S., small microelectronics firms play a major role in developing and marketing many significant innovations.

Another possible constraint on Japanese innovation and basic research is the lack of ties between industry and academia, said Professor Inose. In the U.S., industry often has fertile, symbiotic ties with universities.

The Japanese must also contend with certain cultural factors and attitudes if they are to continue to be competitive in the global microelectronics markets. Professor Inose suggested that Japan's highly touted system of "lifetime employment" may turn out to be a double-edged sword. The practice has been credited for the high productivity and loyalty of the Japanese worker, but it may prove counterproductive in situations involving rapid technological progress. Older workers unfamiliar with new technologies may resent taking instruction and guidance from younger, better-educated subordinates. Hence, Japanese industries must retrain both technical and management employees and treat older workers with special consideration, Professor Inose advised.

Like other countries with growing microelectronics industries, Japan faces an increasing shortage of programmers and software designers. But the Japanese seem slow to recognize the market potential of software. In marked contrast, software is a thriving U.S. industry. Failure to follow suit could prove costly to the Japanese, because it seems likely that the value of software sales will eventually surpass the value of hardware sales as the number of microprocessor and microcomputer applications grows and the cost of hardware falls.

Japan faces a peculiar problem in the

area of office automation and word processors, already a billion-dollar industry in the United States. In addition to requiring two phonetic alphabets, each consisting of some 50-odd characters, typical written communications involve several thousand Chinese characters or *kana*. To complicate matters, a normal string of phonetic characters might be represented by a dozen or more *kana*, each having a different meaning. A recent innovation by a Japanese firm may be the breakthrough needed in Japanese word processing. A word typed on a phonetic keyboard prompts the word processor to display a series of corresponding *kana*. The typist then can select the appropriate *kana* and, if it is frequently used, can program the word processor to automatically select those *kana* whenever that phonetic string appears.

Professor Inose observed that Japan's aggressive pursuit of important world markets for manufactured goods increasingly places it in conflict with other countries. He suggested that Japan therefore consider promoting an "international division of labor" in the production of microelectronics and related software industries. For example, one country could specialize in hardware and another in software. This process has already begun in the Far East, where Taiwan and Hong Kong are beginning to export software — via satellite — to markets in North America.— *J.K.* □

Computers and Politics Together

What happened to that "dramatic breakthrough" in your company's efficiency promised by the latest computer-based management-information technology? Was it illusory, a technical success but an organizational failure, like others before it?

If so, the reason is simple, says Professor Peter G.W. Keen of the Sloan School of Management at M.I.T.: management-information systems specialists consistently underestimate — and therefore take no steps to counteract — the "social inertia" that people build into their methods for handling and using information.

Four realities about decision making are the sources of this "social inertia" encountered by proponents of information systems:

□ New information is not so important in conventional decision making as most computer experts assume. Most decision makers are hesitant to make "breakthrough" choices no matter what evidence is handed to them. "What has worked in the past is most likely to be repeated," says Professor Keen.

□ Most decision makers think of themselves as experimenters, and simplification is one of their basic tools. Simplification, in turn, often means eliminating distractions and irrelevancies — including a lot of information.

□ The complexity of modern organizations assures built-in inertia. No matter how much information supports a potential major change, decision makers' power is often limited to effecting incremental and evolutionary change.

□ Information is power — "a central political resource" in many organizations. So any new information system represents a threat to established data centers and is likely to be resisted in any way possible — including being ignored.

To deal with these sources of "social inertia," experts who would bring sophisticated information systems into use by corporate management must turn to political strategies, harnessing the "pluralism" typical of most business organizations, says Professor Keen. Among his suggestions: mobilize coalitions, convert broad organizational goals into objectives that can be embraced by small units, and simplify concepts to make them seem less threatening and more manageable.

"The simple, central argument is that information-systems development is political as well as — and sometimes far more so than — technical in nature," writes Professor Keen. He defines political know-how as "the process of gaining commitment, building support, and creating momentum for change." He suggests that advocates of management-information systems take lessons from the politicians, whose special talent involves persuading people to correlate their self-interest with larger organizational goals. Information experts need admit no shame in their reliance on these skills: "Politics are inevitable and perhaps desirable in a world where choice is difficult and the future full of ambiguity," says Professor Keen. — *J.M.* □

Energy

Conservation: Not by Price Alone

Can the world make more goods with less energy? The tie between energy consumption and industrial prosperity is strong — but marginally flexible.

In the last 25 years, says Resources for the Future, Inc., in a study for the Electric Power Research Institute (EPRI), each 3 percent increase in per capita gross domestic product (GDP) in the industrial nations has — on average — required a 3.6 percent increase in energy consumption. But the 1973-to-1974 oil price shocks stimulated conservation, and the ratio of energy consumption to GDP has dropped slightly in most countries.

Now, many nations are setting targets for the 1980s of 3 percent annual growth in GDP but only 2 percent annual growth in energy consumption — a difficult goal. Analyzing American industry's responses to the 1973-to-1974 price increases, Resources for the Future tells EPRI that real prices of energy to its consumers must rise 3 percent a year to stimulate and maintain that level of conservation. Given that increases in the cost of raw materials alone translate into smaller energy price increases to consumers, and that energy price hikes must be maintained at 3 percent annually for a decade or more, EPRI is told that conservation by price alone is an unlikely scenario for the 1980s. "It is only prudent to consider additional conservation measures," says Resources for the Future.— *J.M.* □

Centralized Energy: Hard or Soft?

The argument for "soft," solar-based energy is fueled in part by its advocates' wish to escape from the tyranny of centralized, large-scale energy industries. But are such soft energy advocates risking an even greater tyranny?

The question arises out of the hypothesis that reliance on soft energy resources conflicts with America's growing reliance on electricity. If electricity supply falls short under such circumstances, the inevitable result will be rationing and priorities, says A. David Rossin, nuclear research engineer at Commonwealth Edison in Chicago. And such priorities, he argues, "would not be set by individuals but

by government — big, centralized government."

No one can imagine a transition to an increasingly soft energy lifestyle without the availability of hard energy resources. And there is "a serious lack of data on the cost and performance of solar, wind, wood-burning, and other soft-path concepts, especially on a scale widespread enough to affect the need for electric power plants," says Mr. Rossin.

Mr. Rossin worries — along with most of us — about "excessive centralization that can exercise further control over our lives." But he thinks scenarios for "what might happen if the electricity supply begins to fall short of what people need" are a seldom-discussed part of the soft energy path that need some careful study. "The real question is whether it is desirable to pursue decentralization of energy supply as an absolute goal or to permit the diversity we have now, in which anyone who wishes can use decentralized alternatives." — *J.M.* ☐

Last Line

U.S. Innovation: Champions Needed

"People will always innovate. There will always be entrepreneurs. We are seeing more good technology today than we have ever seen."

These statements by Walter J. Cairns, manager of Arthur D. Little Enterprises, Inc. in Cambridge, Mass., run counter to popular wisdom that has the vitality of U.S. innovation at low ebb. Actually, there need be no contradiction. Innovative ideas are plentiful, but so are the hurdles that stand in the way of developing and marketing the products based on those ideas. And the hurdles have changed the route by which many innovations reach the marketplace.

At the root of the problem is the need for capital. Venture capital has always been hard to come by, but it is especially dear these days for an inventor or invention without a track record. Private venture capital firms demand much and give little; government support is minimal (*see "Paving the Way for Energy-Saving Innovations," June/July, pp. 43-53*).

Then why not take an invention or idea to a large company? Exchange pride for practicality: after all, sacrificing the potential benefits (and headaches) of entrepreneurship for licensing — assigning all rights for an invention to a large company in return for a royalty or fee — could be offset by the elimination of personal risk. The trouble is that rejection by companies of an idea originating from outside is very likely, regardless of the idea's merit, says Mr. Cairns, who's had 22 years in the invention management business. He offers the following observations:

☐ "It's a lot easier to argue against the company's putting money on an outside project than it is to fight your battle for limited company capital with the person [in the department] next door.

☐ "The requirements for incoming technology are a lot more stringent than those for internal technology. When outside technology is being offered, it requires usually one person to stick his neck out. If he's wrong, the penalties can be severe; if he's right, the rewards can be impressive — or not." Such sponsors are termed "champions" in the vernacular of the innovation business and they are rare indeed in corporate bureaucracy, where the safest path is the status quo.

☐ "Killing incoming projects or inventions requires no skill at all," but proper evaluation of undeveloped innovation takes lots of talent — and lots of time, an especially precious commodity for those busy executives who have the foresight and expertise to do the best job.

The influence of a highly credible, independent "advocate" can be essential in building bridges between inventor and an established company. Mr. Cairns and his associates have reviewed some 500 disclosures annually since 1958 acting in this role; despite their advocacy of ten to fifteen of these annually, only five to seven of these on the average have been eventually undertaken by large companies. But most independent inventors lack such sophisticated and well-received advocates and it's little wonder that most bright ideas become flashes in the pan. (Typically, resulting royalties — in the \$1-to-2-million range — are shared equally between Arthur D. Little Enterprises and the inventors; and no charges are made to inventors.)

The lack of fiscal incentives for potential licensees is another albatross for innovation to bear. Mr. Cairns suggests remedial provisions in the tax laws: for example, a "double deduction or greater than a one-point-zero deduction on taxes made by manufacturers on royalties to innovation owners." — *L.A.P.* ☐

High Technology Knocking at the Door

The "second industrial revolution" born of today's computers and automatic controls has brought almost unprecedented prosperity to the Massachusetts electronics industry, forcing the state's unemployment rate to among the lowest in the U.S.

But the industry is acutely aware of how fleeting such prosperity can be, and two years ago — even as the boom was beginning — its leaders organized a High-Technology Council to press for conditions to help them stay ahead. Lower taxes were an early goal, leading the council into a little-publicized alliance with taxpayers' groups in support of the "Proposition 2½" tax-cap referendum approved in the state last November.

A year ago, as the industry's rapid expansion led to a growing shortage of qualified workers, the High-Technology Council launched a drive for new technical labor, urging retraining of Massachusetts workers, recruitment of out-of-state workers, and special programs in Massachusetts schools. The "tremendous shortage" of engineers is likely to continue at least for several years, says Alexander V. d'Arbeloff, president of Teradyne, Inc., especially a shortage of competent and aggressive workers — the kind who get ideas and start projects.

Could M.I.T.— which has spawned its share of the firms now so prosperous — help by opening its doors to more students in electronics, computer science, and materials, and by providing part-time, in-plant teaching programs for advanced degrees to qualified workers?

At first blush, President Paul E. Gray's answer did not seem very helpful. He agreed absolutely with the diagnosis that there will be a serious shortage of perhaps 1,000 engineers a year in the next decade. But, said Dr. Gray, M.I.T.'s Department of Electrical Engineering and Computer Science is already swamped with students. Futhermore, the Institute's traditional thesis and residence requirements for every graduate student seem to the faculty a vital expression of the quality that sets an M.I.T. education apart, and compromise is in no one's interest.

M.I.T. is already making significant contributions and "we are actively seeking ways to expand our relationship with industry," Dr. Gray told the High-Technology Council this fall:

□ In the past decade, M.I.T.'s undergraduate engineering enrollments doubled as students watched the new high-technology opportunities take shape. Electrical engineering was the fastest-growing department of all, and it is now bulging at the seams, accommodating one-third of all M.I.T. undergraduates and nearly the same fraction of graduate students. Further increases could be prohibitively expensive, Dr. Gray said.

□ About 10 percent of M.I.T.'s freshmen come from Massachusetts. But in the last five years, 40 percent of its electrical-engineering graduates have stayed here, making the Institute "an important concentrator' of engineering talent," Dr. Gray said.

□ There are close ties between industry and all M.I.T. engineering departments — cooperative study programs for undergraduates and graduate students, lots of research sponsorships, scores of intensive short courses and conferences, and off-campus lectures and video refresher courses. □

Television Can't Come Close

When the Massachusetts High-Technology Council asked M.I.T. to undertake a slower-paced part-time graduate program in electrical engineering for working engineers, the editors of *The Tech*, the Institute's twice-a-week student newspaper, called the request "selfish and perhaps shortsighted."

"By entering into a protracted arrangement with local high-technology industry," said an editorial, "the Institute runs the risk of losing sight of its basic academic orientation. . . . The concept of off-campus programs or videotaped instruction offering the equivalent of an M.I.T. education is, as any undergraduate can tell you, absurd. A good deal of the education one receives here comes from outside the classroom . . . and no amount of television watching can ever come close." □

Animal Disease Analogs

Can we learn about human disease from their analogs in animals? The answer from Dr. James G. Fox has led to a new name for M.I.T.'s Division of Laboratory Animal Medicine: it's now the Division of Comparative Medicine. The group will continue care and supervision of thousands of experimental animals used in research and teaching throughout M.I.T., and at the same time will develop its own research on animal diseases analogous to diseases in humans.

For example, says Dr. Fox, consider the case of the South African degu, a small rodent that develops *diabetes mellitus* spontaneously: study of this subject could lead to a better understanding of diabetes in humans. Other subjects of current research in the division include a central nervous system myoclonic disorder in dogs, a skeletal defect in cats, and alcoholic hepatic disease in rhesus monkeys. □

Spacelab Motion Research

A research program on how changes in the inner ear relate to motion sickness and the aftereffects of weightlessness, proposed by Professor Laurence R. Young, director of the M.I.T. Man-Vehicle Laboratory, will be aboard the first *Spacelab* flight late this year or early next. It's one of only 37 accepted for the first flight by the National Aeronautics and Space Administration and the European Space Agency.

Several experiments are included in the accepted program: the perception of self-motion and eye movements induced by a rotating visual field, the astronauts' awareness of body position in the absence of visual information, the effects of inner-ear changes on leg-muscle activity, the correlation of motion-sickness symptoms with head movements, and the cumulative effects of weightlessness on astronauts' physical abilties.

Space motion sickness may be a special problem on future *Spacelab* flights, according to Dr. Young and his principal coinvestigator, Charles M. Oman, because many of those aboard will be engineers and scientists who have not undergone the extensive training typical of astronauts. Yet they will want to avoid the debilitating effects of space motion sickness that have affected astronauts on several American and Soviet missions. □

Robert Forsberg

How Big Was Big?

Complete the word definitions; then enter the appropriate letters in the diagram to complete a quotation from an early article on the effects of scale in aircraft design.

The first letters of the defined words give the author and title from which the quotation is taken. Black squares in the diagram indicate ends of words; if there is no black square at the right end of the diagram, the word continues on the next line.

The solution will be in the next issue, when another of Mr. Forsberg's puzzles will also appear. Readers are invited to comment—and to suggest favorite texts for future puzzles.

1 L	2 S	3 U	4 H	5 X	■	6 F	7 D	■	8 X	9 S	10 F	11 O	■	12 M	13 P	14 T	15 Y	■	16 D	17 M	■	18 E	19 D	20 H	21 M	22 N
23 P	■	24 B	■	25 I	26 K	27 P	28 U	29 J	■	30 F	31 G	32 D	33 L	34 T	35 Z	36 A	■	37 D	38 P	39 W	40 Y	41 E	■	42 H	43 R	■
44 H	45 B	46 G	■	47 U	48 D	49 J	50 E	■	51 K	52 H	53 S	54 J	55 C	■	56 J	57 M	58 Y	59 B	60 G	■	61 B	62 E	63 L	64 Y	■	65 B
66 W	67 R	68 H	69 Q	■	70 H	71 Y	■	72 N	■	73 C	74 P	75 O	76 Q	77 Y	■	78 H	79 N	80 A	81 F	82 M	83 U	84 Z	■	85 B	86 L	87 Z
88 J	89 X	■	90 E	91 I	92 M	93 R	94 B	95 H	96 G	97 S	98 W	99 J	■	100 Y	101 X	102 A	103 I	104 O	■	105 E	106 B	■	107 B	108 S	109 U	110 A
111 O	■	112 E	113 A	114 Q	115 T	116 G	117 M	■	118 Y	119 H	■	120 Y	■	121 R	122 X	123 L	124 V	125 H	■	126 U	127 B	128 O	■	129 H	■	130 Z
131 C	132 S	133 T	134 E	■	135 N	136 C	137 E	138 G	139 R	140 U	141 D	■	142 U	143 E	144 M	145 Y	■	146 V	147 U	148 J	149 P	■	150 H	151 R	152 D	■
153 G	154 I	155 Y	■	156 J	157 Y	158 H	159 M	160 S	161 R	162 Z	■	163 V	164 B	165 D	166 J	167 Y	■	168 G	169 N	170 S	171 Z	172 B	173 C	174 X	■	175 D
176 H	177 G	■	178 D	179 P	180 Y	181 J	182 U	183 V	184 F	■	185 B	186 S	187 Y	188 E	189 N	■	190 E	191 I	192 S	193 A	194 O	195 Z	196 F	197 N	198 G	■
199 J	200 R	201 U	202 H	203 L	204 O	205 Y	■	206 J	■	207 Z	208 V	209 N	210 U	■	211 J	212 E	213 L	214 P	■	215 Z	216 E	■	217 F	218 C	219 G	220 I
221 V	222 E	223 M	■	224 R	225 G	226 N	227 C	228 A	■	229 C	230 F	■	231 C	232 G	233 Y	234 B	235 O	236 X	237 A	238 Z	239 K	■	240 H	241 Z	■	242 J
■	243 I	244 D	245 X	246 T	247 L	■	248 U	249 D	250 E	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■

A Works of Word V
113 237 80 36 228 110 102 193

B Factor of expansion of the universe (2 words)
45 164 85 185 65 234 59 172 106
61 94 24 127 107

C Comic opera by Weber, 1811 (2 words)
218 229 173 227 136 73 55 131 231

D Dominant art style, late 18th-early 19th century, esp. in France
249 141 37 32 19 175 165 152 48
178 16 7 244

E Babbage's mechanical computer, c.1813 (2 words)
50 143 18 216 112 90 212 190 137
134 250 222 41 105 188 62

F A Borough of London
184 230 217 6 10 81 196 30

G Helter skelter; in all directions (3 words)
232 96 46 219 177 168 60 225 116
138 153 31 198

H Vitreous material for lasers (3 words)
20 44 70 158 95 52 78 150 202
240 119 68 129 4 176 125 42

I Ettarre's Love (Arthurian legends)
220 91 25 103 191 154 243

J "Master_______" (Kipling, *The Mary Gloster*) (4 words)
206 156 181 56 148 242 49 211 166
199 29 88 54 99

K Librettist of *The Beggar's Opera* London, 1728
51 26 239

L Impalpable; celestial
203 1 33 86 123 63 213 247

M British statesman, Viceroy of India, 1936-43
144 82 17 92 21 117 57 223 159
12

N A coronary diagnostic procedure
79 22 226 169 209 189 197 72 135

O Novel by Samuel Johnson, 1759
111 75 11 194 128 104 204 235

P Popular tune by Paul Lincke (with "The")
23 214 179 38 149 13 27 74

Q Sprite
69 76 114

R Mechanical or recursive computational procedure
93 121 161 43 67 139 151 200 224

S A legendary king of Athens
97 132 186 192 2 170 108 9 160
53

T Bright double star in Orion
14 34 133 115 246

U Character in Shakespeare's *Henry IV* (full name)
126 47 201 140 28 147 109 83 210
248 142 3 182

V Italian Humanist, 1380-1459 (see Word A)
146 183 124 163 221 208

W Medieval French verse form
98 66 39

X Claudius Ptolemy's treatise, AD 150
122 8 101 245 89 5 236 174

Y American musicologist. 1897- *Lexicon of Musical Invective,* 1955 (full name)
180 187 233 157 71 145 120 167 205
77 118 40 58 64 100 15 155

Z Double-reed instrument of mournful tone (2 words)
84 241 207 130 87 195 171 162 215
238 35

Solution to November/December Crostic

Now, for the space of several moments,* fearful powers were in play — streams of thousands of a hundred thousand volts... They could hardly be confined to their office, they tried to escape through other outlets. There were explosions like pistol shots, blue sparks on the measuring apparatus; long lightnings crackled along the walls.

Thomas Mann, "The Magic Mountain" 1924. Translated by H. T. Lowe-Porter

*"two seconds" in the original

A Taffeta
B Hippogryph
C Orlovsky
D Mark Gable Foundation
E Affray
F Sredni Vashtar
G Mother of us All
H Axolotl
I Night on the Town
J Nuclear Fusion
K Tsetse
L Hepplewhite
M Elwood P. Dowd
N Moessbauer Effect
O Ash
P Geddes
Q Irene
R Collegiate Assessor
S Mock Turtle
T Orpheus
U Ultrashort
V Northern Lights
W The well-connected
X Astrophysics
Y Issoudun
Z Nephele

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